

DESCRIPTION

[Title of Invention]

METHOD FOR MANUFACTURING MAGNETIC-DISK SUBSTRATE, AND
5 POLISHING PAD

[Technical Field]

[0001] The present invention relates to a method for manufacturing a
magnetic-disk substrate and a polishing pad that is used in manufacturing a
10 magnetic-disk substrate.

[Background Art]

[0002] Glass substrates have conventionally been used favorably in magnetic
disks that are used as one type of information recording media. Nowadays, the
density of magnetic recording has been increased to meet the demand for an
15 increase in the storage capacity of hard disk drives. Following this, the
magnetic recording information area has been made smaller by making the
flying height of the magnetic head from the magnetic recording surface
extremely low. In such a magnetic-disk glass substrate, in order to achieve a
reduction in the flying height of a magnetic head required for high recording
20 density hard disk drives, there is increasing demand for a reduction in surface
unevenness of the substrate, especially, a reduction in microwaviness.

[0003] In contrast, a method for manufacturing a glass substrate for an
information recording medium that can accurately control microwaviness of the
surface and be used as a substrate for an information recording medium
25 supporting high density recording is known (PLT1)

This manufacturing method is a method for manufacturing a glass
substrate for an information recording medium including a polishing step of
setting a glass substrate for an information recording medium between upper
and lower surface plates to which polishing pads of a soft polisher are attached,

and polishing both main surfaces. With this manufacturing method, using a phenomenon in which the value of microwaviness of the main surfaces of the glass substrate for an information recording medium that was subjected to the polishing step depends on the value of surface roughness of the surface of the polishing pads that are used in the polishing step, the surface roughness of the surface of the polishing pads that are used in the polishing step is selected such that microwaviness of the main surfaces of the glass substrate for an information recording medium that was subjected to the polishing step is a predetermined value. For example, assume that surface roughness Rz (maximum height) of a polishing pad that is selected is 20 μm or less. In this case, the surface roughness Rz of the polishing pad is measured using a stylus type surface roughness tester. It should be noted that a wavelength (period) bandwidth of microwaviness here is 2 μm to 4 mm.

[Citation List]

15 [Patent Literature]

[0004] [PLT1]: JP 2002-92867A

[Summary of Invention]

[Technical Problem]

[0005] In recent years, following a reduction in size of a magnetic head, a reduction in the flying height of a magnetic head, and an increase in rotation speed of a magnetic disk, and the like, a wavelength bandwidth of microwaviness that needs to be reduced in a magnetic-disk glass substrate has become smaller. However, in the case where the surface roughness Rz (maximum height) of the polishing pad in the above-described manufacturing method is set in the above-described numerical value range, microwaviness having a wavelength from 2 μm to 4 mm, which is a conventional wide wavelength bandwidth, can be reduced, but microwaviness having a wavelength from 50 to 200 μm in the glass substrate cannot be reduced. An aluminum alloy substrate also has similar problems to the reduction in microwaviness having a wavelength from 50 to 200 μm in a glass substrate.

[0006] In view of this, an object of the present invention is to provide a method for manufacturing a magnetic-disk substrate that is capable of achieving a reduction in microwaviness having a wavelength from 50 to 200 μm and a polishing pad that is used in this manufacturing method.

5 [Solution to Problem]

[0007] In order to resolve the above-described conventional issues, the inventor of the present invention studies the surface of a polishing pad in detail.

First, the inventor measured the surface roughness R_z of various
10 polishing pads using a stylus type surface roughness tester, selected a polishing pad having an extremely small R_z value among the measured R_z , and performed polishing. However, microwaviness having a wavelength from 50 μm to 200 μm of the glass substrate could not be reduced. In other words, the surface roughness R_z measured by the stylus type surface roughness tester
15 could not serve as an index for a reduction in microwaviness having a wavelength from 50 μm to 200 μm . Thus, it was not clear what type of polishing pad needed to be used in order to achieve a reduction in the microwaviness having a wavelength from 50 μm to 200 μm of the glass substrate.

20 In view of this, the inventor studied the surface of various polishing pads in detail, using a scanning electron microscope (SEM). As a result, when observing the surfaces of polishing pads at a resolution at which the surface of the polishing pad could be observed in a wavelength from 50 μm to 200 μm , which is a wavelength bandwidth of a microwaviness target, the inventor found
25 that the polishing pads were different in the surface state. Specifically, the inventor found that the surface of the polishing pad whose microwaviness having a wavelength from 50 to 200 μm could not be reduced was in a state in which the tips of the walls surrounding foam pores had fine tears in the longitudinal direction and the surface became rough around an opening of the
30 foam pores, or in other words, in a state in which the tip of the wall around the

opening become rough, i.e., a "finely split" shape, and thought that the surface shape of the outermost layer of the polishing pad had an influence on microwaviness having a wavelength from 50 to 200 μm . It should be noted that the above-described "finely split" state is also a state in which the tip of the wall surrounding the opening tears finely to form what can also be referred to as a "frayed" state in which the surface appears to be frayed. The above-described "finely split" state can also be referred to as "locally frayed disturbance". Hereinafter, an unevenness state of the tip of the wall surrounding the opening is referred to as a "finely split" state.

10 In view of this, when the inventor studied this "fine splitting", in the case where the surface of a polishing pad that had a large amount of surface unevenness resulting from such "fine splitting" (having unevenness of a large number of pieces that were formed by the tip of the wall surrounding the opening tearing finely due to "fine splitting") or that was in a "finely split" state in which the surface had unevenness due to large surface unevenness resulting from the "fine splitting" (increased size of unevenness of the large number of pieces that were formed by the tip of the wall surrounding the opening tearing finely due to the "fine splitting"), and the surface of the polishing pad that did not have "fine splitting" or had "fine splitting" to a small extent was measured using a conventional stylus type surface roughness tester, the inventor found that the surface roughness R_z that was obtained from the measurement results did not have a correlation with microwaviness having a wavelength from 50 to 200 μm . With the stylus type surface roughness tester, the size of a tip of a stylus is two times or more (several tens of micrometers to several hundreds of micrometers, for example) the diameter of an opening in the surface of the polishing pad, which is the measurement target, so that the tip of the stylus does not drop into the opening. Also, it is conceivable that when measurement is performed by pressing the stylus against the polishing pad, the tip of the stylus measured the surface after flattening the surface unevenness of the "fine splitting". It was found from this that the surface state of the outermost layer

of the polishing pad to be used in polishing could not be accurately measured using the stylus type surface roughness tester.

In view of this, in order to measure the surface state of the outermost layer of the polishing pad, the inventor conceived to measure surface roughness using a contactless method instead of a contact method such as a stylus type surface roughness tester, and thus arrived at this invention.

[0008] A method for manufacturing a magnetic-disk substrate of the present invention has the following aspects.

[0009] [Aspect 1]

10 A method for manufacturing a magnetic-disk substrate, comprising:
polishing both main surfaces of a substrate by sandwiching the substrate with a pair of polishing pads, supplying a slurry containing polishing abrasive particles between the polishing pads and the substrate, and sliding the polishing pads and the substrate relative to each other,

15 the polishing pads respectively having a resin foam layer having a plurality of openings in a surface, and

when information on a three-dimensional shape of a rectangular surface of 1600×1200 pixels, where one pixel is a rectangular surface of 0.37 μm×0.37 μm, is obtained as information on a three-dimensional shape of a surface of the polishing pads, from captured images of the surface of the polishing pads that are obtained with a rectangular region as a field of view of capturing, by a method of repeatedly performing image capture using a capturing means for as long as the images are in focus, with a focus point being lowered by 5 μm each time in a height direction from a location of the focus point at which a highest position of the surface of the polishing pads is in focus, and an arithmetic mean roughness Ra of the surface of the polishing pads is derived from the information on the three-dimensional shape, the Ra being 0.5 μm or less.

The rectangular region is 592 μm×444 μm, for example.

More specifically, the captured image is obtained, for example, by capturing the surface using a capturing camera at a magnification of 500x with a rectangular region of $592\ \mu\text{m} \times 444\ \mu\text{m}$ as the field of view of the capturing, where one pixel is a rectangular surface of $0.37\ \mu\text{m} \times 0.37\ \mu\text{m}$. At this time, the image capture is started at a location of the focus point at which the highest position of the surface of the polishing pads is in focus, and image capture is repeatedly performed with the position of the capturing camera being moved by $5\ \mu\text{m}$ each time in the height direction until any of the pixels in the images comes into focus. The image capture is then stopped when none of the pixels come into focus. An image processing apparatus obtains information on the three-dimensional shape of the surface of the polishing pads from the captured images obtained by performing image capture at an interval of $5\ \mu\text{m}$ in the height direction. At this time, three-dimensional information about a rectangular region of 1600×1200 pixels, where a rectangular surface of $0.37\ \mu\text{m} \times 0.37\ \mu\text{m}$ is one pixel, can be obtained.

[0010] [Aspect 2]

The method for manufacturing a magnetic-disk substrate according to aspect 1, in which the polishing is polishing for setting a root mean square roughness R_q of microwaviness having a wavelength from $50\ \mu\text{m}$ or more to $200\ \mu\text{m}$ or less on the main surfaces of the substrate to $0.06\ \text{nm}$ or less.

[0011] [Aspect 3]

The method for manufacturing a magnetic-disk substrate according to aspect 1 or 2, in which the root mean square roughness R_q of the microwaviness on the main surfaces of the substrate before the polishing is performed is $0.6\ \text{nm}$ or less.

[0012] [Aspect 4]

It is preferable that the method for manufacturing a magnetic-disk substrate according to any one of aspects 1 to 3, in which a 100% tensile modulus of a resin material in the resin foam layer is $200\ \text{kgf/cm}^2$ or less.

[0013] [Aspect 5]

The method for manufacturing a magnetic-disk substrate according to any one of aspects 1 to 4, in which the polishing abrasive particles are colloidal silica having an average particle diameter from 5 nm or more to 50 nm or less.

[0014] [Aspect 6]

5 The method for manufacturing a magnetic-disk substrate according to any one of aspects 1 to 5, in which a relationship between a root mean square roughness Rq of microwaviness having a wavelength from 50 μm or more to 200 μm or less on a main surface of a substrate on which the polishing was performed and an arithmetic mean roughness Ra of a polishing pad surface
10 that was used in the polishing is derived in advance, a polishing pad having the arithmetic mean roughness Ra of a polishing pad surface that achieves desired microwaviness on the main surface of the substrate is selected using the relationship, and the selected polishing pad is used in the polishing.

[0015] [Aspect 7]

15 The method for manufacturing a magnetic-disk substrate according to any one of aspects 1 to 6, in which the information on the three-dimensional shape includes information on an uneven shape formed on a tip of a wall surrounding a hole in the resin foam layer.

[0016] [Aspect 8]

20 The method for manufacturing a magnetic-disk substrate according to aspect 6, in which the polishing pad has been dressed, and the arithmetic mean roughness Ra of the polishing pad that is obtained by a stylus type surface roughness tester before the dressing is 0.8 μm or less.

[0017] [Aspect 9]

25 A method for manufacturing a magnetic disk, in which at least a magnetic layer is formed on a main surface of a magnetic-disk substrate manufactured by the method for manufacturing a magnetic-disk substrate.

[0018] [Aspect 10]

A polishing pad to be used in manufacturing a magnetic-disk substrate,

the polishing pad having a resin foam layer that has a plurality of openings in a surface, and

when information on a three-dimensional shape of a rectangular surface of 1600×1200 pixels, where one pixel is a rectangular surface of 0.37 μm×0.37 μm, is obtained as information on a three-dimensional shape of a surface of the polishing pad, from captured images that are obtained with a rectangular region of the surface of the polishing pad as a field of view of capturing, by a method of repeatedly performing image capture using a capturing means for as long as the images are in focus, with a focus point being lowered by 5 μm each time in a height direction from a location of the focus point at which a highest position of the surface of the polishing pad is in focus, and an arithmetic mean roughness Ra of the surface of the polishing pad is derived from the information on the three-dimensional shape, the Ra being 0.5 μm or less.

[Advantageous Effects of the Invention]

[0019] With the method for manufacturing a magnetic-disk substrate and the polishing pad described above, microwaviness having a wavelength from 50 μm to 200 μm in the substrate can be reduced.

[Brief Description of Drawings]

[0020] FIGS. 1A and 1B are schematic diagrams of a polishing device that is used in second polishing according to this embodiment.

FIG. 2 is a diagram illustrating polishing that is performed by the polishing device shown in FIGS. 1A and 1B.

FIG. 3 is a diagram illustrating the structure of a polishing pad that is used in this embodiment.

FIG. 4 is a diagram illustrating a method for measuring a three-dimensional shape of a surface of the polishing pad performed in this embodiment.

[Description of Embodiments]

[0021] Hereinafter, a method for manufacturing a magnetic-disk glass substrate and a polishing pad according to the present invention will be described in detail. It should be noted that although the magnetic-disk substrate of the present invention can be applied to an aluminum alloy substrate besides the glass substrate, the magnetic-disk glass substrate is used as this embodiment in the following description.

In the present embodiment, a magnetic-disk glass substrate to be used in a magnetic disk has a disk shape, and a central portion thereof is concentrically hollowed out so that the glass substrate has a ring shape, and the glass substrate rotates using the center of the ring as a rotation axis. The magnetic disk can be obtained by laminating a magnetic layer or the like on the magnetic-disk glass substrate. Therefore, it is important to accurately control surface unevenness of a magnetic-disk glass substrate. With the method for manufacturing a magnetic-disk glass substrate of the present embodiment, a root mean square roughness R_q of microwaviness having a wavelength from 50 to 200 μm on main surfaces of the glass substrate can be reduced by polishing the main surfaces of the glass substrate, and a root mean square roughness R_q of 0.6 nm or less before polishing can be preferably reduced to 0.06 nm or less. In this case, a polishing pad that is used in polishing has a resin foam layer having a plurality of openings in the surface. The arithmetic mean roughness R_a , which will be described below, of the surface of this polishing pad is 0.5 μm or less. The arithmetic mean roughness R_a can be derived by obtaining information on the three-dimensional shape of a surface of the polishing pad from an image obtained by capturing the surface of the polishing pad and using this information. The information on this three-dimensional shape includes information on an uneven shape formed on the tip of a wall surrounding a hole in the resin foam layer.

It should be noted that definitions of surface roughness including the root mean square roughness R_q and the arithmetic mean roughness R_a of microwaviness having a wavelength from 50 to 200 μm and microwaviness

having a wavelength from 2 μm to 4 mm in this specification conform to JIS B 0601:2001.

[0022] An example of a method for manufacturing a magnetic-disk glass substrate of the present embodiment will be described below.

5 First, a glass blank, which serves as a raw material for a plate-shaped magnetic-disk glass substrate having a pair of main surfaces, is molded. Next, this glass blank is processed as appropriate to produce a ring-shaped (annular) glass substrate that has a hole in the central portion and in which an edge portion is chamfered. Accordingly, the glass substrate is produced.
10 Thereafter, polishing is performed on the main surfaces to reduce the root mean square roughness R_q of microwaviness having a wavelength from 50 μm to 200 μm . For example, the root mean square roughness R_q of the microwaviness having a wavelength from 50 μm to 200 μm can be reduced to 0.06 nm or less. Polishing may be divided into a plurality of processes as
15 needed. Also, the main surface may be ground, an edge surface (including chamfered portion) may be polished, and chemical strengthening may be performed as needed. In this case, the order of processing may be determined as appropriate.

Hereinafter, the respective processing will be described.

20 [0023] (a) Glass blank molding processing

A float method is used, for example, in molding of a glass blank. In the glass blank molding processing, first, a sheet of plate glass having the above-described composition, for example, is obtained by continuously pouring molten glass into a bath filled with molten metal such as tin. The molten
25 glass moves in a traveling direction in the bath where the temperature is strictly controlled, and ultimately a sheet of plate glass with a desired thickness and width is formed. A plate-shaped glass blank with a predetermined shape (a quadrangular shape in a plan view, for example) from which a magnetic-disk glass substrate is to be made is cut out from this sheet of
30 plate glass.

Also, the plate-shaped glass blank can also be molded by a press molding method, for example, instead of the float method. Furthermore, the plate-shaped glass blank can be manufactured using a known manufacturing method such as a down draw method, a redraw method, or a fusion method. A disk-shaped glass blank from which a magnetic-disk glass substrate is to be made is cut out by appropriately shaping the sheet of plate glass manufactured by these known manufacturing methods.

[0024] (b) Shaping processing

Next, in shaping processing, a disk-shaped glass substrate having a circular through hole is produced by forming a circular hole using a known processing method after the glass blank molding processing. Thereafter, chamfering may be further performed. Also, the main surfaces may be ground in order to adjust the thickness, reduce the flatness, or the like.

[0025] (c) First polishing

Next, first polishing is performed on the main surfaces of the glass substrate. The first polishing is performed in order to mirror-polish the main surfaces. Specifically, the main surfaces on both sides of the glass substrate are polished while holding the glass substrate in a holding hole provided in a holding member (carrier) that is attached to a double-side polishing device. The machining allowance for first polishing is from about several micrometers to 100 μm , for example. The first polishing is performed in order to eliminate scratches and distortions that remain on the main surfaces and to adjust minute unevenness of the surface, for example. It should be noted that in order to further reduce or more finely adjust surface unevenness, the first polishing may be divided into a plurality of polishing processes.

[0026] In the first polishing, the glass substrate is polished while supplying a polishing slurry using a known double-side polishing device that includes an upper surface plate, a lower surface plate, an internal gear, carriers, and a sun gear, and that has a planetary gear mechanism. In the first polishing, the polishing slurry containing polishing abrasive particles (loose abrasive

particles) is used. Abrasive particles (particle size: diameter from about 0.3 to 3 μm) of cerium oxide, zirconia, or colloidal silica, for example, are used as the loose abrasive particles that are used in the first polishing. In the double-side polishing device, the glass substrate is held between a pair of the upper and lower surface plates. Planar polishing pads (polishers made of resin, for example) having an annular shape as a whole are attached to the upper surface of the lower surface plate and the bottom surface of the upper surface plate. The glass substrate and the surface plates are moved relative to each other by moving one or both of the upper surface plate and the lower surface plate, so that the both main surfaces of the glass substrate can be polished.

[0027] (d) Chemical strengthening

The glass substrate can be chemically strengthened as appropriate. A molten liquid obtained by heating potassium nitrate, sodium nitrate, or a mixture thereof, for example, to from 300°C to 500°C can be used as a chemical strengthening liquid. The glass substrate is then immersed in the chemical strengthening liquid for 1 hour to 10 hours, for example.

By immersing the glass substrate in the chemical strengthening liquid, lithium ions and sodium ions in the glass composition of the surface layer of the glass substrate are respectively replaced by sodium ions and potassium ions with a relatively large ion radius in the chemical strengthening liquid, a compressive stress layer is formed in a surface layer portion, and thus the glass substrate is strengthened.

Although timing at which the chemical strengthening is performed can be determined as appropriate, it is particularly preferable that polishing is performed after the chemical strengthening because it is possible to smoothing the surface and remove foreign substances adhering to the surface of the glass substrate by the chemical strengthening. It is not essential to perform the chemical strengthening.

[0028] (e) Second polishing (final polishing)

Next, second polishing is performed on the glass substrate that was subjected to the chemical strengthening. The second polishing is performed in order to mirror-polish the main surfaces. A double-side polishing device having a configuration similar to the double-side polishing device that is used
5 in the first polishing is used in the second polishing as well. The machining allowance for the second polishing is about 0.5 μm to 10 μm , for example.

In the second polishing, the polishing is performed using a slurry containing loose abrasive particles. Colloidal silica is preferably used as the loose abrasive particle. The average particle diameter of the colloidal silica is
10 preferably 5 nm or more to 50 nm or less in that the root mean square roughness R_q of the microwaviness having a wavelength from 50 to 200 μm on a main surface of a glass substrate G is reduced. If the average particle diameter is larger than 50 nm, there is a concern that the microwaviness having a wavelength from 50 to 200 μm cannot be reduced sufficiently. Also,
15 there is a concern that the surface roughness cannot be reduced sufficiently. On the other hand, if the average particle diameter is less than 5 nm, there is a concern that the polishing rate will dramatically decrease and productivity will decrease.

It should be noted that in the present embodiment, the above-described
20 average particle diameter denotes a particle diameter at which a cumulative curve reaches 50% when the cumulative curve is derived by setting the total volume of powder particles in the particle size distribution measured by a laser diffraction method to 100% (also referred to as "cumulative average particle diameter (50% diameter)", or D50).

25 FIGS. 1A and 1B are schematic diagrams of a polishing device 10 that is used in the second polishing. A similar device can also be used in the first polishing.

[0029] As shown in FIGS. 1A and 1B, the polishing device 10 includes a lower surface plate 12, an upper surface plate 14, an internal gear 16, carriers 18, and
30 polishing pads 20, a sun gear 22, and an internal gear 24.

The polishing device 10 sandwiches the internal gear 16 between the lower surface plate 12 and the upper surface plate 14 from above and below. The internal gear 16 holds a plurality of carriers 18 at the time of polishing. Five carriers 18 are shown in FIG. 1B. The polishing pads 20 are attached in
5 a planar manner to the lower surface plate 12 and the upper surface plate 14. The lower surface plate 12 and the upper surface plate 14 are configured to rotate (revolve) around a rotation axis of the lower surface plate 12 and the upper surface plate 14.

[0030] As shown in FIG. 2, the carriers 18 are arranged such that the main
10 surface of the glass substrate G on the lower side abuts against the polishing pad 20 on the lower surface plate 12 and the main surface of the glass substrate G on the upper side abuts against the polishing pad 20 on the upper surface plate 14. By performing polishing in such a state, the main surfaces on both sides of the glass substrate G that was formed into an annular shape can be
15 polished.

[0031] As shown in FIG. 1B, the annular glass substrate G is held in a circular hole provided in each carrier 18. On the other hand, the glass substrate G is held above the lower surface plate 12 by the carrier 18 having a gear 19 on the outer circumference. The carrier 18 is engaged with the sun gear 22 and the
20 internal gear 24 provided in the lower surface plate 12. By rotating the sun gear 22 in the direction of the arrow shown in FIG. 1B, the carriers 208 respectively revolve while rotating as planet gears in the arrow direction. Accordingly, the glass substrate G is polished using the polishing pads 20. At the time of polishing, the glass substrate G is polished by being pressed at
25 0.002 to 0.02 MPa, for example. The slurry that is used in the polishing is supplied to the upper surface plate 14 as shown in FIG. 1A, flows to the lower surface plate 12, and is recovered therefrom into an external container.

[0032] It should be noted that the type, particle diameter, variation in the particle diameter of the loose abrasive particles that are used in the second
30 polishing, the hardness of a resin used for the polishing pad 20, the opening

diameter of a pore, which will be described later, of the surface of the polishing pad 20, or the like are changed from those in the first polishing as appropriate. In the present embodiment, it is preferable to adjust the arithmetic mean roughness Ra of the surface of the polishing pad 20 such that the root mean square roughness Rq of microwaviness having a wavelength from 50 to 200 μm is 0.06 nm or less of the polished glass substrate at least in the final polishing.

It should be noted that in order to further reduce and finely adjust the surface unevenness of the glass substrate G, the respective polishing may be further divided into a plurality of polishing processes. In this case, in each polishing process, it is preferable to appropriately adjust the type, particle diameter, variation in the particle diameter of the loose abrasive particles, the hardness of the resin that is used for the polishing pad, the opening diameter of the pore in the surface of the polishing pad.

After the second polishing, the glass substrate G is cleaned to produce a magnetic-disk glass substrate.

[0033] (Polishing pad)

Next, the polishing pad 20 that is used in the second polishing will be described below in detail.

The polishing pad 20 is made of resin foam having a plurality of openings on its surface, and is made of polyurethane foam, for example. The diameter of the openings in the surface of the polishing pad 20 is preferably 5 μm or more to 20 μm or less. In the case where the opening diameter is smaller than 5 μm , it is difficult for a foam material having a structure in which a large number of small holes having a droplet shape are formed to store a slurry and to appropriately supply the stored slurry, and thus the polishing rate decreases, as a result of which polishing cannot be performed. On the other hand, in the case where the diameter of the opening is larger than 20 μm , the surface roughness of the polishing pad 20 increases, and thus the microwaviness having a wavelength from 50 to 200 μm cannot be reduced.

The arithmetic mean roughness Ra of the surface of the polishing pad 20 is 0.5 μm or less. Specifically, the arithmetic mean roughness Ra can be derived by obtaining information on the three-dimensional shape of a surface of the polishing pad 20 from an image obtained by capturing the surface of the polishing pad 20 and using this information. Optical measurement using this captured image will be described later. Although there is no particular limitation on a lower limit of the arithmetic mean roughness Ra of the surface of the polishing pad 20, the lower limit is 0.1 μm , for example. If Ra is less than 0.1 μm , there are cases in which the polishing rate decreases and productivity deteriorates.

The root mean square roughness Rq of the microwaviness having a wavelength from 50 μm to 200 μm on the main surface of the glass substrate G can be reduced through polishing in which such a polishing pad 20 is used. Preferably, the root mean square roughness Rq can be reduced to 0.06 nm or less. In this case, it is preferable that the root mean square roughness Rq of the microwaviness having a wavelength from 50 to 200 μm on the glass substrate G before being subjected to the second polishing is 0.6 nm or less. If the Rq of the glass substrate G before being subjected to the second polishing is larger than 0.6 nm, there are cases in which the machining allowance for polishing to set Rq to 0.06 nm or less increases and thus productivity deteriorates. Also, there are cases in which significant depressions (roll off) occur in the shape of the outermost circumferential portion of the main surface.

Also, it is preferable that polishing in which the polishing pad of the present embodiment is used is performed on the main surface that was chemically strengthened. A compressive stress layer is formed on the main surface of the glass substrate that was chemically strengthened, and thus if polishing is performed, there are cases in which microwaviness and roughness cannot be sufficiently reduced due to the release of compressive stress being locally disturbed by the "fine splitting" of the polishing pad. In the polishing pad of the present embodiment, "fine splitting" is suppressed such that the

arithmetic mean roughness Ra of the surface of the polishing pad is 0.5 μm or less, and thus microwaviness and roughness can be favorably reduced.

The arithmetic mean roughness Ra of the surface roughness of the glass substrate G after the second polishing is 0.2 nm or less, and preferably 0.15 nm or less. Here, the arithmetic mean roughness Ra of the surface roughness is a value obtained when measurement is performed on a measurement area of 1 $\mu\text{m} \times 1 \mu\text{m}$ using an AFM (atomic force microscope) at a resolution of 256 $\times$ 256 pixels.

There is a correlation between the arithmetic mean roughness Ra of the surface roughness of the polishing pad and the root mean square roughness Rq of the microwaviness having a wavelength from 50 μm to 200 μm on the main polished surface, as described later. Therefore, a plurality of types of polishing pads having different arithmetic mean roughnesses Ra of the surface roughness are prepared in advance, and in order to achieve a desired microwaviness on the main surface of the substrate, a polishing pad is selected among the plurality of types of polishing pads as appropriate. In this case, it is preferable that a relationship between the root mean square roughness Rq of the microwaviness having a wavelength from 50 μm or more to 200 μm or less on the main surface of the polished substrate and the arithmetic mean roughness Ra of the surface of the polishing pad used in the polishing is derived in advance, a polishing pad having an arithmetic mean roughness Ra of the polishing pad surface that achieves a desired microwaviness on the main surface of the substrate is selected using the above-described relationship, and the selected polishing pad is used in polishing.

[0034] Because the polishing pad 20 is made of resin foam (resin foam layer), the surface of the polishing pad has pore openings. Thus, the slurry containing the loose abrasive particles can enter cavities in the polishing pad 20 through the openings, and polishing can be efficiently performed. However, if polishing is performed many times, there are cases in which the polishing rate decreases and polishing efficiency deteriorates. In such cases, the

polishing rate can be recovered by dressing the polishing pad 20. On the other hand, the surface of the polishing pad 20, that is, the tips of the walls surrounding the holes (pores) in the resin foam layer are forcibly ground by the dressing, and thus are in a "finely split" state, causing fine unevenness. When
5 the shape of the surface of the polishing pad 20 whose microwaviness having a wavelength from 50 to 200 μm cannot be reduced was observed using a scanning electron microscope, it was found that the tips of resin portions around openings of many foam pores were in the "finely split" state. In addition, it was found that tip portions in the "finely split" state were thin and
10 formed a film. The tip in such a "finely split" state has an extremely low rigidity and is likely to bend with a slight force. It is conceivable that such a "finely split" state is formed by the surface layer of the polishing pad being torn by diamond abrasive particles at the time of the dressing. A surface state in which the surface has unevenness resulting from such a "finely split" state
15 cannot be measured by a stylus type surface roughness tester. With the stylus type surface roughness tester, the size of a tip of a stylus is two times or more (several tens of micrometers to several hundreds of micrometers, for example) the diameter of the openings in the surface of the polishing pad 20, which is the measurement target, such that the tip of the stylus does not drop into the
20 openings. Also, measurement is performed by pressing the stylus against the polishing pad. Thus, measurement is performed with the tip of the stylus pressing down the "finely split" state. Therefore, the surface unevenness including the "finely split" state cannot be measured from the measurement results obtained by the stylus type surface roughness tester. Thus, optical
25 measurement that uses a captured image is used in the present embodiment. The microwaviness having a wavelength from 50 to 200 μm on the main surface of the glass substrate G can be reduced by reducing the arithmetic mean roughness R_a of the surface of the polishing pad 20 obtained by the optical measurement. Preferably, the root mean square roughness R_q of the
30 microwaviness having a wavelength from 50 to 200 μm on the main surface of

the glass substrate G can be reduced to 0.06 nm or less. In this case, it is preferable that the root mean square roughness R_q of the microwaviness having a wavelength from 50 to 200 μm on the main surface of the glass substrate G before polishing is 0.6 nm or less.

5 [0035] It should be noted that the modulus (tensile stress) of a resin material in the resin foam layer that is used for the polishing pad 20 is preferably 200 kgf/cm^2 or less in that the root mean square roughness R_q of the microwaviness having a wavelength from 50 to 200 μm is efficiently reduced to 0.06 nm or less without minute scratches. Here, the above-described modulus is a 100%
10 modulus. It should be noted that it is more preferable that the modulus is 100 kgf/cm^2 or less to prevent the formation of minute scratches on the glass substrate G. On the other hand, if the modulus is smaller than 50 kgf/cm^2 , there is a concern that productivity will decrease due to a reduction in the polishing rate. Moreover, if the above-described modulus is smaller than 50
15 kgf/cm^2 , there are cases in which the glass main surface gently slopes toward an outer circumferential edge surface in a region around the outer circumferential edge surface of the glass main surface of the glass substrate so as to form a curve, and the degree of smoothness is disturbed. Disturbance of smoothness in the region around the outer circumferential edge surface of the
20 glass main surface is not favorable in that in order to increase the storage capacity, a magnetic layer is formed on the entire glass main surface and recording or reading of magnetic information is accurately performed to the vicinity of the outer circumferential edge surface of the glass main surface. Therefore, although there is no particular limitation on the lower limit of the
25 above-described modulus, the lower limit is 50 kgf/cm^2 , for example. A tensile modulus of the resin material is measured by a tensile tester (tensilon tester).

Also, an arithmetic mean roughness R_a' of the surface roughness of the polishing pad 20 before dressing is preferably 0.8 μm or less. The arithmetic mean roughness R_a' is measured using a stylus type surface roughness
30 measurement device with a stylus having a radius of curvature of a tip of

several tens to several hundreds of micrometers. By setting Ra' of the surface roughness of the polishing pad 20 before dressing to 0.8 μm or less, the arithmetic mean roughness Ra of the surface of the polishing pad that is measured using a imaging camera can also be easily set to 0.5 μm or less after
5 the dressing. This is because the dressing can be performed more stably as the surface roughness of the polishing pad decreases. In other words, irregularity resulting from the dressing does not occur over the entire surface of the polishing pad.

[0036] The polishing pad 20 is made of a closed-cell resin foam in a new state
10 in which the polishing pad 20 has not been used (has not used for polishing at all in the past), and thus the polishing pad 20 does not have openings on its surface. Thus, before use of the polishing pad 20 in polishing, the surface is ground by dressing along a dotted line X shown in FIG. 3 such that the surface has a plurality of openings, such as holes having openings of a diameter of 5 to
15 20 μm and a depth of 10 to 600 μm , for example. In other words, it is preferable to use a polishing pad having an opening diameter of 5 μm or more to 20 μm or less in the polishing. If the opening diameter is less than 5 μm , there are cases in which the polishing rate decreases and productivity decreases. On the other hand, if the opening diameter is larger than 20 μm ,
20 there are cases in which the microwaviness having a wavelength bandwidth of 50 to 200 μm cannot be reduced. Also, it is preferable to use a polishing pad in which the holes (pores) have a depth of 10 μm or more to 600 μm or less. If the depth is less than 10 μm , there are cases in which the polishing rate decreases and productivity decreases. On the other hand, if the depth is larger than 600
25 μm , there are cases in which a compressive deformation amount of the polishing pad 20 increases due to an increase in the thickness of a nap layer in which air holes are formed continuously, a high pressure is likely to be locally applied to the outermost circumferential portion of the substrate, and the roll off amount increases. It should be noted that the diameter of the openings or

the depth of the holes (pores) can be measured by observing the surface or a cross-section of the polishing pad using a SEM.

It is preferable that the information on the three-dimensional shape of the surface of the polishing pad 20 of the present embodiment is information on
 5 a surface state that is used in the polishing.

The polishing pad 20 has been described above.

[0037] (Surface measurement of polishing pad)

FIG. 4 is a diagram illustrating a method for measuring the three-dimensional shape of the surface of the polishing pad 20 that is
 10 performed in the present embodiment.

[0038] As described above, in order to reduce the microwaviness having a wavelength from 2 μm to 4 mm of the glass substrate, the surface roughness Rz of a polishing pad that is used in conventional polishing and measured using a stylus type surface roughness tester was set to 20 μm or less. In this case, the
 15 arithmetic mean roughness Ra' is approximately 3.0 μm or less, but in a state in which the surface is in the "finely split" state described above, surface unevenness resulting from the "fine splitting" cannot be measured with a stylus type surface roughness tester. Therefore, in the present embodiment, the arithmetic mean roughness Ra is measured by optical measurement in which a
 20 captured image is used, instead of the stylus type surface roughness tester.

[0039] Specifically, the image of the surface is captured using a capturing camera 40 at a magnification of 500x with a rectangular region of 600 μm ×450 μm as a field of view of capture, where one pixel is a rectangular surface of 0.37 μm ×0.37 μm . At this time, the image capture is started at a location at which
 25 the highest position of the surface of the polishing pad 20 is in focus, and image capture is repeatedly performed with the position of the camera 40 being moved by 5 μm each time in the height direction until any of the pixels in the image comes into focus. The image capture is then stopped when none of the pixels come into focus.

A CCD camera can be used as the capturing camera 40, for example. This camera may be used in combination with an optical microscope, or a device in which they are integrated may be used.

[0040] The captured images obtained by capturing the surface at an interval of 5 μm in this manner are respectively sent to an image processing apparatus 42 and image processing is performed. The image processing apparatus 42 obtains information on the three-dimensional shape of the surface of the polishing pad 20 per pixel. The information on this three-dimensional shape includes information on an uneven shape formed on the tips of the walls surrounding the holes in the resin foam layer, that is, information on the "finely split" state. Specifically, the image processing apparatus 42 calculates information on positions of the pixels in the height direction from image data of captured images obtained at an interval of 5 μm . There is no particular limitation on the method for calculating the information on the positions of the pixels in the height direction from the image data, and a known method can be used. For example, the information on the positions in the height direction is calculated by determining information on the positions (focus point positions) in the height direction when the pixels are respectively in focus from the image data of the captured images at an interval of 5 μm . In this case, focus point positions are derived every 5 μm , and thus preferably position information can be calculated finely as positions of less than 5 μm by interpolating the information on the positions in the height direction around the pixels obtained at an interval of 5 μm .

[0041] The image processing apparatus 42 is configured with a computer, and the above-described image processing performs operations by calling and executing software stored in a memory of the computer. The software can be software on the market or original software as long as the above-described processing can be appropriately executed.

[0042] The information on the three-dimensional shape of the surface of the three-dimensional polishing pad 20 that can be obtained by such image

processing can reproduce surface unevenness resulting from the “finely split” state of the surface of resin foam, which is different from measurement in which a conventional stylus type surface roughness tester is used. The image processing apparatus 42 calculates the arithmetic mean roughness Ra using the information on the three-dimensional shape of the surface of this three dimensional polishing pad 20.

[0043] The root mean square roughness Rq of the microwaviness having a wavelength from 50 to 200 μm in the magnetic-disk glass substrate that is produced can be derived using a surface shape measurement device, with respect to a region having a radius of 14 mm to 31.5 mm of the main surface of the glass substrate. Specifically, the surface shape is measured where a measurement pitch in a radius direction is 0.01 mm and a measurement region per lap in the circumferential direction is 1024. A laser doppler vibrometer (LDV) can be used as the surface shape measurement device. This measurement device can perform measurement in a wide wavelength bandwidth from surface roughness to waviness. The microwaviness having a wavelength from 50 μm to 200 μm can be derived using data filtered using a band-pass filter supporting a wavelength from 50 μm to 200 μm .

[0044] In the method for manufacturing the magnetic-disk glass substrate of the present embodiment, the polishing pad 20 that is used in the second polishing is used to polish the glass substrate G after the dressing. One polishing pad 20 is used in the second polishing several times. A single execution of second polishing is processing for reducing Rq of the microwaviness having a wavelength from 50 to 200 μm on the main surface of the glass substrate G to 0.06 nm or less.

The polishing rate of the polishing pad 20 decreases in accordance with an increase in the number of instances of the second polishing performed on the glass substrate G. Thus, in the case where the polishing rate is smaller than or equal to an allowable range, the polishing pad 20 is dressed. It is preferable that dressing is performed under other conditions other than those for initial

dressing that is first performed on a new polishing pad 20 that does not have openings on its surface. In the case of distinguishing this dressing from the initial dressing in the description, this dressing is called second onward dressing. In the case of referring to the initial dressing and the second onward dressing collectively without distinguishing therebetween, this dressing is simply called dressing. The surface of the polishing pad is more likely to be "finely split" in the second onward dressing than in the initial dressing, and thus the second onward dressing is preferably performed under other conditions. This is thought to be because a large number of openings are already formed on the surface of the polishing pad even in a state prior to the dressing.

It should be noted that in the case where the arithmetic mean roughness R_a of the surface of the polishing pad after being dressed exceeds $0.5\text{ }\mu\text{m}$, even if the surface of the polishing pad 20 adapts well to loose abrasive particles, R_q of the microwaviness having a wavelength from $50\text{ }\mu\text{m}$ to $200\text{ }\mu\text{m}$ of the glass substrate G cannot be reduced to 0.06 nm or less. On the other hand, in the case where the arithmetic mean roughness R_a of the surface of the polishing pad after being dressed by a method using the above-described capturing camera is $0.5\text{ }\mu\text{m}$ or less, R_q of the microwaviness having a wavelength from 50 to $200\text{ }\mu\text{m}$ of the glass substrate G can be reduced to 0.06 nm or less.

[0045] The dressing referred to herein uses the polishing device 10 shown in FIGS. 1A, 1B, and 2, and uses a dresser having attached thereto an abrasive to which diamond abrasive particles, for example, are affixed to both surfaces of a substrate, instead of the glass substrate G. It is sufficient to supply water, for example, instead of a polishing liquid. In order to suppress "fine splitting" of the surface of the polishing pad 20 resulting from the initial dressing and "fine splitting" of the surface of the polishing pad 20 resulting from the second onward dressing, it is preferable to appropriately adjust the average particle diameter of abrasive particles that are used in the dressing, particle diameter

dispersion, a resin material for fixing abrasive particles, surface plate load at the time of dressing, a rotation rate, rotation and revolution of a planet gear, and other conditions.

[0046] It is preferable that the diamond abrasive particles that are used in dressing have a particle diameter of 10 to 30 μm . Although diamond abrasive particles having a small particle diameter are more effective in suppressing "fine splitting" of the polishing pad surface, if the particle diameter is smaller than 10 μm , there are cases in which a removal rate of the polishing pads decreases and it takes time to perform the dressing operation, leading to a reduction in productivity. On the other hand, if the particle diameter is larger than 30 μm , there are cases in which the size of surface unevenness resulting from "fine splitting" increases or the amount of surface unevenness resulting from "fine splitting" increases, and Ra of the surface of the polishing pad cannot be sufficiently reduced.

[0047] Also, it is preferable to reduce the load applied by the surface plates at the time of dressing below that at the time of polishing. Specifically, it is preferable that the pressure applied to the polishing pad is 0.001 to 0.005 MPa. When the load at the time of dressing is smaller than that at the time of polishing, an increase in "fine splitting" of the polishing pad surface is more effectively suppressed, but if the pressure applied to the polishing pad is less than 0.001 MPa, there are cases in which a removal rate of the polishing pads decreases and it takes time to perform dressing, leading to a reduction in productivity. On the other hand, if the pressure applied to the polishing pad is larger than 0.005 MPa, there are cases in which the size of surface unevenness resulting from "fine splitting" increases or the amount of surface unevenness resulting from "fine splitting" increases, and Ra of the surface of the polishing pad cannot be sufficiently reduced.

[0048] Also, it is preferable that the relative speed between the dresser and the polishing surface plates (polishing pads) is 1.5 to 3 times that at the time of the polishing. Although a higher relative speed is more effective in suppressing

"fine splitting" of the polishing pad surface, if the relative speed at the time of dressing is higher than three times that at the time of polishing, there are cases in which water is not sufficiently supplied to the surface of the polishing pad, and the dressing cannot be evenly performed. On the other hand, if the
5 relative speed at the time of dressing is less than 1.5-fold, there are cases in which the diamond abrasive particles eat into the surface of the polishing pad, and "fine splitting" cannot be suppressed.

Also, by performing adjustment to reduce the load at the time of dressing and increase the relative speed with respect to the polishing pads, it is
10 possible to perform dressing while further favorably preventing "fine splitting".
[0049] Also, it is preferable that when the upper surface plate is raised immediately after dressing, the upper surface plate is raised while maintaining movement (rotation) of at least one of the rotating upper surface plate and carriers (dressers). By doing so, it is possible to prevent the occurrence of "fine
15 splitting" on the polishing pad surface resulting from the upper surface plate having a slight wobble when the upper surface plate is raised after dressing. Therefore, when the upper surface plate is raised, it is preferable to raise the upper surface plate while moving (rotating) at least one of the upper surface plate and the carriers (dressers) in order to achieve the polishing pad 20 having
20 an arithmetic mean roughness R_a of 0.5 μm or less.

When dressing is performed, it is sufficient that the above-described conditions are adjusted as appropriate and that dressing is performed by combining the conditions.

[0050] Also, a correspondence relationship between the arithmetic mean
25 roughness R_a of the surface of the polishing pad 20 before dressing and conditions for dressing (conditions such as dressing time, surface plate load, rotation rate, and the like) to set the arithmetic mean roughness R_a of the surface of the polishing pad 20 before dressing to 0.5 μm or less is derived in advance, and the above-described dressing conditions are determined using the
30 above-described correspondence relationship and the information on

measurement result of the arithmetic mean roughness Ra of the surface of the polishing pad before dressing when the polishing pad 20 is dressed. Accordingly, disturbance in the surface shape of the polishing pad 20 resulting from "fine splitting" can be suppressed.

5 [0051] Also, with regard to the second onward dressing, it is also possible to perform dressing in which a cleaning liquid is sprayed on the polishing pad 20 by ejecting the cleaning liquid as mist droplets without using the polishing device 10. Specifically, a nozzle having a discharge opening that is elongated vertically and has a central portion that enlarges forwardly is moved over the
10 entire surface of the polishing pad, mist droplets of a cleaning liquid that have a particle diameter of 1 μm or more to 300 μm or less are produced, and these mist droplets are caused to collide with the polishing pad 20 at a speed of 10 m/sec or more to 500 m/sec or less. At this time, by adjusting various conditions as appropriate, polishing abrasive particles accumulated in the foam
15 pores can be favorably removed without causing new "fine splitting" on the polishing pad surface. It is preferable to apply this dressing method to polishing pads that are used in polishing. By doing so, it is possible to suppress any advance in the extent of the "finely split" state of the surface of the polishing pad resulting from dressing being performed multiple times using
20 a diamond dresser and to prevent deterioration in microwaviness of the glass substrate obtained by polishing performed after the second onward dressing.

Also, in the second onward dressing, it is preferable that dressing in which abrasive particles such as the above-described diamond abrasive particles are used and dressing in which a cleaning liquid is sprayed on the
25 polishing pad 20 by ejecting the cleaning liquid as mist droplets are used in combination. Such dressing can be performed gently compared to dressing in which diamond abrasive particles are used, and thus it is possible to suppress any advance in the extent of the "finely split" state of the polishing pad 20 after being dressed.

As described above, the polishing pad 20 that is used in the second polishing of the present embodiment is a polishing pad on which the initial dressing and the second onward dressing were performed, and when information on the three-dimensional shape of the surface of the polishing pad 20 is obtained from an image obtained by capturing the surface of the polishing pad 20, the arithmetic mean roughness Ra of the surface of the polishing pad 20 that is obtained from the information is 0.5 μm or less.

Although the present embodiment was described using a glass substrate, as described above, the present embodiment can be applied to an aluminum alloy substrate besides the glass substrate. The glass substrate has a higher rigidity (is harder) than the aluminum alloy substrate, and thus if the glass substrate is used, in order to increase productivity, it is preferable to increase the modulus of the polishing pad 20 and improve the polishing rate. On the other hand, the rigidity of a tip of the surface unevenness of "fine splitting" is likely to increase due to the high modulus of the polishing pad 20 compared to the case of an aluminum alloy substrate, and thus microwaviness is likely to deteriorate compared to the aluminum alloy substrate and minute scratches are likely to form. Therefore, it is preferable to apply the polishing of this invention to a glass substrate.

[0052] [Working examples]

In order to study the effects of an optical measurement method (method of the present embodiment) in which an image obtained by capturing the polishing pad of the present embodiment is used and the effects of the polishing pad in the second polishing, the second polishing was performed using different types of polishing pads. The glass substrate G that are used was a 2.5-inch magnetic-disk glass substrate. The surface unevenness of the glass substrate G before polishing was measured using an optical surface shape measurement device. The root mean square roughness Rq of the microwaviness having a wavelength from 50 to 200 μm on the main surface was 0.1 to 1.0 nm.

A polishing pad was made of a polyurethane resin whose surface layer portion has foam having a structure in which a large number of holes having a droplet shape are formed, as shown in FIG. 3, and was dressed in advance using the polishing device 10 shown in FIGS. 1A and 1B. In the dressing, a dresser having diamond abrasive particles was used and the above-described processing conditions were adjusted as appropriate. Thus, a plurality of openings were formed on the surface of each polishing pad by the dressing. By using foam having the structure in which a large number of holes having a droplet shape were formed, the openings of a portion that came into contact with the glass substrate could be reduced, and the surface roughness of the polished glass substrate and microwaviness having a wavelength from 50 to 200 μm could be reduced. Also, this foam can store a larger amount of abrasives than a ball-shaped foam structure or a foam structure having a shape in which a diameter did not change in the depth direction, and thus it is possible to stably supply the abrasives and maintain a high polishing rate for a long time. Here, a polishing pad having an average value of the opening diameter of 15 μm was used.

[0053] When the glass substrate G was polished, a pressure of 0.01 MPa was applied to the glass substrate G using the polishing device 10 shown in FIGS. 1A and 1B, and the glass substrate G was polished while supplying a slurry containing polishing abrasive particles of colloidal silica having an average particle diameter of 30 nm to the glass substrate G. The machining allowance for polishing was set to 5 μm .

On the other hand, with regard to the surface of the polishing pad, the arithmetic mean roughness R_a' was derived using a stylus type surface roughness tester in examples 1 to 4 (conventional method), and the arithmetic mean roughness R_a was derived using a captured image through optical measurement of the present embodiment in examples 5 to 8 (embodiment method).

Furthermore, the surface unevenness of the polished glass substrate G was measured using the above-described optical surface shape measurement device, and the root mean square roughness R_q of the microwaviness having a wavelength from 50 to 200 μm was derived.

5 [0054] Tables 1 and 2 show the arithmetic mean roughnesses R_a and R_a' of the surface of the polishing pad immediately before polishing when polishing was performed using various types of polishing pads and the root mean square roughnesses R_q and R_q' of the microwaviness of the glass substrates when the second polishing was performed using these polishing pads. In the examples 1
10 to 4, the root mean square roughness R_q' of the microwaviness having a wavelength from 2 μm to 4 mm and the root mean square roughness R_q of the microwaviness having a wavelength from 50 μm to 200 μm were derived. In the examples 5 to 8, the root mean square roughness R_q of the microwaviness having a wavelength from 50 μm to 200 μm was derived. It should be noted
15 that the root mean square roughness of the microwaviness having a wavelength from 50 μm to 200 μm is denoted by R_q and the root mean square roughness of the microwaviness having a wavelength from 2 μm to 4 mm is denoted by R_q' . Also, the arithmetic mean roughness of the surface of the polishing pad derived by the conventional method is denoted by R_a' and the
20 arithmetic mean roughness of the surface of the polishing pad derived by the present embodiment method is denoted by R_a .

The root mean square roughness R_q' of the microwaviness having a wavelength from 2 μm to 4 mm was measured using a known multifunctional surface analyzer described in PLT 1. With this analyzer, light was separated,
25 the separated light was reflected on both a test surface and a reference surface, and then the root mean square roughness R_q' of the microwaviness having a wavelength from 2 μm to 4 mm was calculated from interference fringes generated when the light was recombined. A rectangular region of approximately 500 $\mu\text{m} \times$ approximately 600 μm (approximately 250,000 pixels)

around the middle circumference of the glass substrate was selected as a measurement region.

[0055] [Table 1]

	Ra' of polishing pad surface by conventional method (μm)	Rq' of microwaviness having wavelength from 2 μm to 4 mm on glass substrate surface (nm)	Rq of microwaviness having wavelength from 50 μm to 200 μm on glass substrate surface (nm)
Ex. 1	0.31	0.4	0.072
Ex. 2	0.24	0.36	0.08
Ex. 3	0.13	0.32	0.09
Ex. 4	0.25	0.36	0.15

5 [0056] [Table 2]

	Ra of polishing pad surface by embodiment method (μm)	Rq of microwaviness having wavelength from 50 μm to 200 μm on glass substrate surface (nm)
Ex. 5	0.25	0.048
Ex. 6	0.32	0.050
Ex. 7	0.5	0.054
Ex. 8	0.75	0.092

[0057] According to Table 1, it was found that the surface roughness of the polishing pad derived by the conventional method had a correlation with the root mean square roughness Rq' of the microwaviness having a wavelength from 2 μm to 4 mm on the surface of the glass substrate, but did not have a correlation with the root mean square roughness Rq of the microwaviness having a wavelength from 50 μm to 200 μm . Therefore, even if the surface roughness of the polishing pad derived by the conventional method was reduced, the microwaviness having a wavelength from 50 μm to 200 μm could not be reduced.

On the other hand, according to Table 2, it was found that the arithmetic mean roughness Ra of the surface of the polishing pad derived by the present embodiment method had a correlation with the root mean square roughness Rq of the microwaviness having a wavelength from 50 μm to 200 μm on the surface of the glass substrate. In addition, it was found that by setting the arithmetic mean roughness Ra of the surface of the polishing pad to 0.5 μm or less, the root mean square roughness Rq of the microwaviness having a wavelength from 50 μm to 200 μm was dramatically reduced compared to the case where the arithmetic mean roughness Ra was 0.75 μm . In particular, it was found that by setting the arithmetic mean roughness Ra of the surface of the polishing pad to 0.5 μm or less, the root mean square roughness Rq of the microwaviness having a wavelength from 50 μm to 200 μm could be greatly reduced to 0.06 nm or less.

An adherent layer, a base layer, a magnetic recording layer, a protecting layer, and a lubricant layer were formed on the glass main surface of the magnetic-disk glass substrates obtained in the examples 5 to 8 in this order near from the glass main surface, using a sputtering method and a vapor deposition method to manufacture magnetic disks. Each of the manufactured magnetic disks was incorporated in a hard disk drive (HDD) along with a magnetic head (DFH head) equipped with a dynamic flying height (DFH) mechanism, and a flying resistance test was performed. A magnetic head having a femtoslider was used, and a flying height of a slider surface was set to 9 nm and a backoff amount of a magnetic-head element portion (gap between the magnetic-head element portion and the magnetic-disk surface) was set to 1 nm. The HDD was placed in an incubator having a humidity of 80% at 80°C and random seeking was performed for 30 days. After evaluation, the magnetic head was taken out and dirt on the slider surface was evaluated using an optical microscope. As a result, in the case where the magnetic disks of the examples 5 to 7 were used, dirt was not observed in particular, but in the case where the magnetic disk of the example 8 was used, scratch marks were

observed in a direction corresponding to the rotation direction of the magnetic disk around the element portion.

Based on the above-described results, it was confirmed that by setting the microwaviness R_q to 0.06 nm or less, flying characteristics were favorable, even in the state in which the element portion was extremely close to the magnetic disk using the DFH head.

[0058] With regard to an image obtained by capturing the surface of a polishing pad, when information on the three-dimensional shape of the surface of this polishing pad was obtained using the above-described embodiment method, it was important for the arithmetic mean roughness R_a of the surface of the polishing pad that was derived from the information to be 0.5 μm or less.

In this manner, it was possible to check the effects of the present embodiment method and the effects of setting the arithmetic mean roughness R_a of the surface of the polishing pad to 0.5 μm or less.

[0059] Next, polishing pads in which the modulus (100% modulus) was changed by changing the type of resin of the polishing pads were prepared, and the second polishing was performed. All of the polishing pads respectively had an arithmetic mean roughness R_a , which was derived by the present embodiment method, of the polishing pad of 0.5 μm or less. After the second polishing was respectively performed on 1000 polishing pads, the glass substrates were cleaned, the number of minute scratches present on the main surface were counted using an optical surface analyzer, and the level was determined based on ten stages. A smaller level indicates fewer minute scratches and a more favorable result. Regarding the levels, specifically, the number of minute scratches on a glass substrate that served as a predetermined reference were counted, and when the level of the minute scratches was defined as level 10 with the count number at that time being 100%, the level in the case where the count number of minute scratches in later-described examples 9 to 14 was 0 to 10% of the number of minute scratches on the reference glass substrate was defined as level 1, the level in

the case of 11 to 20% thereof was defined as level 2, the level in the case of 21 to 30% was defined as level 3, and levels were respectively defined up to level 9 (81 to 90%) in a similar manner. Table 3 below shows the results.

[0060] [Table 3]

	Modulus of polishing pad resin (kgf/cm ²)	minute scratch formation level
Ex. 9	50	level 1
Ex. 10	70	level 1
Ex. 11	100	level 3
Ex. 12	130	level 3
Ex. 13	200	level 5
Ex. 14	240	level 8

5 [0061] Although the root mean square roughness Rq of the microwaviness having a wavelength from 50 μm to 200 μm on the glass substrate G after the second polishing was 0.06 nm or less in the examples 9 to 14, a difference in the level of formation of minute scratches was found. It is conceivable that conditions were set such that scratches remaining on the main surface were
10 eliminated by the first polishing or processing prior to the first polishing in the examples 9 to 14, and thus these minute scratches were formed by the polishing pad accidentally scratching the surface of the glass substrate in the second polishing. In the case where the level was greater than 5, it meant that there was a risk of poor production stability of second polishing. Therefore, it
15 was preferable to set the modulus to 200 kgf/cm² or less because the production stability increased. Also, it was more preferable to set the modulus to 130 kgf/cm² or less. Also, it was even more preferable to set the modulus to 70 kgf/cm² or less. On the other hand, when the modulus was set to 50 kgf/cm² or less, abrasion of the polishing pad was hastened and production efficiency
20 decreased.

[0062] Although a method for manufacturing a magnetic-disk substrate and polishing pads that are used in manufacturing a magnetic-disk substrate of the present invention were described in detail above, the present invention is not

limited to the above-described embodiment or working examples, and it will be appreciated that various improvements and modifications can be made without departing from the gist of the present invention.

[Descriptions of Reference Numerals]

5	[0063]	10	Polishing device
		12	Lower surface plate
		14	Upper surface plate
		16	Internal gear
		18	Carrier
10		20	Polishing pad
		22	Sun gear
		24	Internal gear
		28	Coolant
		30	Pump
15		32	Filter

CLAIMS

1. A method for manufacturing a magnetic-disk substrate, comprising:
polishing both main surfaces of a substrate by sandwiching the substrate with a pair of polishing pads, supplying a slurry containing polishing abrasive particles between the polishing pads and the substrate, and sliding the polishing pads and the substrate relative to each other,
the polishing pads respectively having a resin foam layer having a plurality of openings in a surface, the resin foam layer being made of polyurethane foam, and
when information on a three-dimensional shape of a rectangular surface of 1600×1200 pixels, where one pixel is a rectangular surface of 0.37 μm ×0.37 μm , is obtained as information on a three-dimensional shape of a surface of the polishing pads, from captured images of the surface of the polishing pads that are obtained with a rectangular region as a field of view of capturing, by a method of repeatedly performing image capture using a capturing means for as long as the images are in focus, with a focus point being lowered by 5 μm each time in a height direction from a location of the focus point at which a highest position of the surface of the polishing pads is in focus, and an arithmetic mean roughness Ra of the surface of the polishing pads is derived from the information on the three-dimensional shape, the Ra being 0.5 μm or less.
2. The method for manufacturing a magnetic-disk substrate according to claim 1, wherein an average value of opening diameters of the plurality of the openings is from 5 μm to 20 μm .
3. The method for manufacturing a magnetic-disk substrate according to claim 1 or 2, wherein the resin foam layer has holes with a depth of 10 μm or more to 600 μm or less.
4. The method for manufacturing a magnetic-disk substrate according to any one of claims 1 to 3, wherein the polishing abrasive particles are colloidal silica having an average particle diameter from 5 nm or more to 50 nm or less.

5. A method for manufacturing a magnetic disk, in which at least a magnetic layer is formed on a main surface of a magnetic-disk substrate manufactured by the method for manufacturing a magnetic-disk substrate according to any one of claims 1 to 4.

6. A polishing pad to be used in a polishing process for polishing a surface of a substrate,

the polishing pad having a resin foam layer that has a plurality of openings in a surface, the resin foam layer being made of polyurethane foam, and

when information on a three-dimensional shape of a rectangular surface of 1600×1200 pixels, where one pixel is a rectangular surface of 0.37 μm×0.37 μm, is obtained as information on a three-dimensional shape of a surface of the polishing pad, from captured images that are obtained with a rectangular region of the surface of the polishing pad as a field of view of capturing, by a method of repeatedly performing image capture using a capturing means for as long as the images are in focus, with a focus point being lowered by 5 μm each time in a height direction from a location of the focus point at which a highest position of the surface of the polishing pad is in focus, and an arithmetic mean roughness Ra of the surface of the polishing pad is derived from the information on the three-dimensional shape, the Ra being 0.5 μm or less.

7. The polishing pad according to claim 6, wherein a tensile modulus of a resin material in the resin foam layer is 200 kgf/cm² or less.

8. The polishing pad according to claim 6 or 7, wherein an average value of opening diameters of the plurality of the openings is from 5 μm to 20 μm.

9. The polishing pad according to any one of claims 6 to 8, wherein the resin foam layer has holes with a depth of 10 μm or more to 600 μm or less.

10. The polishing pad according to any one of claims 6 to 9, wherein the polishing pad is used in the polishing process for polishing a surface of a

substrate with a slurry containing polishing abrasive particles of colloidal silica.