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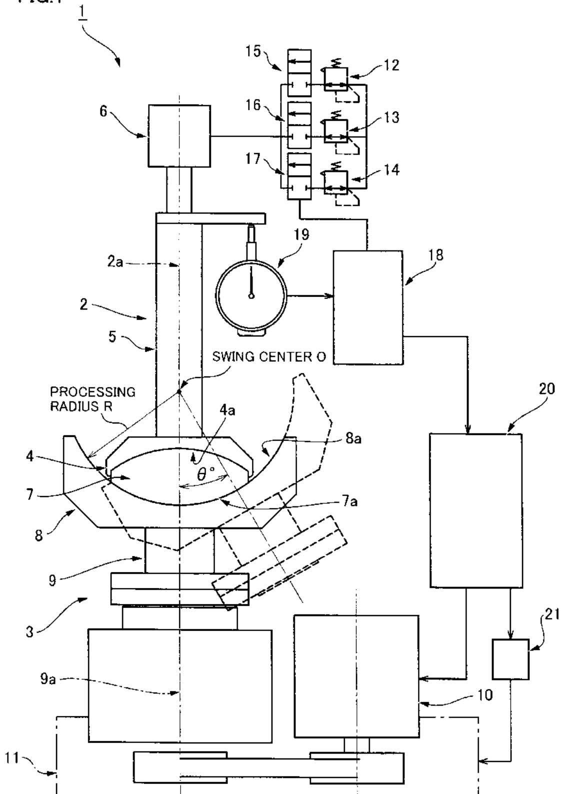
(54) LENS SPHERICAL SURFACE GRINDING METHOD USING DISH-SHAPED GRINDSTONE

(57) A spherical core type lens grinding device (1) performs an operation wherein a dish-shaped grindstone (8) provided with a spherical grindstone surface (8a) which is equipped with diamond abrasive grains, is pressed against a surface-to-be-ground (7a) of a lens blank (7) to be ground, and wherein the dish-shaped grindstone (8) is rotated and is simultaneously swung, resulting in said surface-to-be-ground (7a) being ground to a spherical surface. In an initial-stage grinding process, grinding is performed at first processing pressure and first rotational speed. In an intermediate-stage grinding process, grinding is performed at second processing pressure and second rotational speed. In a last-stage grinding process, grinding is performed at third processing pressure and third rotational speed. The second processing pressure is a pressure at which the spherical grindstone surface (8a) can bite into the lens blank (7). The biting amount of the dish-shaped grindstone (8) is obtained from the hardness of the lens blank (7) and the contact area between the surface-to-be-ground (7a) and the spherical grindstone surface (8a). The second processing pressure is calculated from the biting amount thus obtained. A coarse grinding process and a precision grinding process are unified into a single process. Therefore, the surface of the lens blank can be ground to a spherical surface by using only a dish-shaped grindstone used for precision grinding.

FIG.1



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Description

TECHNICAL FIELD

[0001] The present invention relates to a spherical surface lens grinding method using a spherical core-type lens grinding device. More particularly, the present invention relates to a lens spherical surface grinding method in which a coarse grinding process and a precision grinding process are unified into a single process, and the coarse grinding and precision grinding of the lens blank can be carried out in continuous fashion using only a dish-shaped grindstone for precision grinding use.

BACKGROUND ART

[0002] In spherical surface lens grinding, coarse grinding is applied to a columnar lens blank obtained by cutting a lens blank composed of a press-molded article, or round rod-shaped lens blank (coarse grinding process), and obtaining a coarse grinding lens provided with an approximately spherical lens surface. Precision grinding is next applied to the spherical lens surface of the coarse grinding lens (precision grinding process) to obtain a precision grinding lens provided with a spherical lens surface with predetermined shape precision. The spherical lens surface obtained by grinding is polished, and a lens provided with a lens spherical surface having a desired final shape precision is obtained.

[0003] In this manner, conventional spherical surface lens grinding includes a coarse grinding process and a precision grinding process. In the coarse grinding process, coarse grinding is carried out using a grinder that uses a cup-shaped grindstone; and in the precision grinding process, precision grinding is carried using a grinding device that uses a dish-shaped grindstone. These spherical surface lens grinding methods are disclosed in Patent Documents 1, 2, and 3. In Patent Documents 1 and 2, the cup-shaped grindstone and the dish-shaped grindstone are switched in the same grinding device in order to carry out coarse grinding and precision grinding without using separate devices. In Patent Document 3, a method is disclosed in which precision grinding is carried out using a cup-shaped grindstone that is used for coarse grinding.

[Prior Art Documents]

[Patent Documents]

[0004]

[Patent Document 1] Japanese Laid-open Patent Application No. 2006-297520
[Patent Document 2] Japanese Laid-open Patent Application No. 2009-66724
[Patent Document 3] Japanese Laid-open Patent Application No. 2009-90414

DISCLOSURE OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0005] In a spherical surface lens grinding method comprising a coarse grinding process and a precision grinding process, the following problems need to be solved. First, due to the difficulty of maintaining manufacturing precision during coarse grinding, there are instances in which the dish-shaped grindstone is severely worn down due to variability in the shape of the lens blank in the coarse grinding process, and the precision of the precision grinding is difficult to maintain. Also, different manufacturing techniques are required for both coarse grinding and precision grinding, and technicians experienced in both of the manufacturing techniques are required.

[0006] In view of the foregoing points, an object of the present invention is to provide a spherical surface lens grinding method in which a coarse grinding process and a precision grinding process are unified, grinding is applied to the surface of the lens blank using only the dish-shaped tool used in precision grinding, and lens spherical surface in a precision-grinded state that can be transferred to the polishing process can be obtained.

MEANS TO SOLVE THE PROBLEMS

[0007] To solve the problems described above, according to the present invention, there is provided a lens spherical surface grinding method using a dish-shaped grindstone in which a dish-shaped grindstone having a spherical grindstone surface provided with diamond abrasive grains is pressed at a predetermined pressure against a surface-to-be-ground of a grinding target lens blank, and in such a state, the surface-to-be-ground is ground on a spherical surface while the dish-shaped grindstone is rotated and swung at a predetermined rotational speed, the method characterized in comprising:

an initial-stage grinding process for performing grinding in which the processing pressure is a first processing pressure and the rotational speed is a first rotational speed;
an intermediate-stage grinding process for performing grinding in which the processing pressure is a second processing pressure and the rotational speed is a second rotational speed; and
a last-stage grinding process for performing grinding in which the processing pressure is a third processing pressure and the rotational speed is a third rotational speed, wherein
the second processing pressure is a pressure at which the spherical grindstone surface can bite into the lens blank, a biting amount of the dish-shaped grindstone is obtained from a hardness of the lens blank and a contact area between the surface-to-be-ground of the lens blank and the spherical grindstone surface of the dish-shaped grindstone, and the second processing pressure is calculated on the basis of the biting amount;
the second rotational speed is set to a rotational speed at which the diamond abrasive grains of the dish-shaped grindstone can bite into the lens blank in the case that the processing pressure is set to the second processing pressure;
the first processing pressure is set to a value less than the second processing pressure and the first rotational speed is set to a value less than the second rotational speed; and
the third processing pressure is set to a value less than the first processing pressure and the third rotational speed is set to a value less than the second rotational speed but greater than the first rotational speed.

[0008] The phrase "rotational speed at which the abrasive grains can bite into the lens blank" described above refers to a rotational speed that is equal or less than the maximum rotational speed at which the change in processing time substantially disappears in the case that the processing pressure is set to the second processing pressure and the rotational speed of the dish-shaped grindstone has been changed. In other words, at a rotational speed greater than the maximum rotational speed, the processing time is not shortened, and slipping occurs between the spherical grindstone surface of the dish-shaped grindstone and the surface-to-be-ground of the lens blank, resulting in a state in which the abrasive grains cannot bite into the surface of the lens blank.

[0009] Here, the initial-stage grinding process can be carried out until a state is formed in which the surface-to-be-ground of the lens blank is in contact with the entire spherical grindstone surface, and the intermediate-stage grinding process can be carried out until a state is formed in which a center thickness of the lens blank is greater than a target value by a dimension set in advance.

[0010] Also, it is preferred that a region in which the surface-to-be-ground of the lens blank slides on the spherical grindstone surface of the dish-shaped grindstone be periodically changed in at least the intermediate-stage grinding process.

[0011] In the present invention, in the case that the hardness of the lens blank has a Knoop hardness of 630, the second processing pressure can be 10 kg/cm^2 and the second rotational speed can be 1,500 rpm, the first processing pressure can be 2 kg/cm^2 and the first rotational speed can be 400 to 600 rpm, and the third processing pressure can be 1.5 kg/cm^2 and the third rotational speed can be 1,000 rpm.

[0012] Next, the spherical core-type lens grinding device of the present invention is characterized in comprising:

a lens holder for holding a lens blank;
a dish-shaped grindstone provided with a spherical grindstone surface against which the surface-to-be-ground of the lens blank held in the lens holder is pressed,
a pressurizing mechanism with which the first processing pressure, the second processing pressure, and the third processing pressure can be selectively applied as the pressure for pressing the lens blank against the spherical grindstone surface;
a rotation mechanism for causing the disc-shaped grindstone to rotate;
a swinging mechanism for causing the dish-shaped grindstone to swing; and
a controller for controlling the driving of the pressurizing mechanism, the rotation mechanism, and the swinging mechanism, and causing the grinding method according to any of claims 1 through 5 to be executed.

EFFECT OF THE INVENTION

[0013] According to the present invention, a lens is processed only by a precision grinding technique, whereby simplification of the processing technique, unification of the equipment, and unification of management can be ensured. It is thereby possible to improve the precision of the grinding of the lens spherical surface and the quality of the product.

BRIEF DESCRIPTION OF THE DRAWINGS

[0014]

FIG. 1 is a structural view of a spherical core-type lens grinding device which carries out lens spherical surface grinding according to the method of the present invention;

FIG. 2 is a general flow chart showing the grinding operation of the device in FIG. 1;

FIG. 3 is a graph showing the relationship between the processing pressure and the processing time in lens grinding process; and

FIG. 4 is a graph showing the relationship between the rotational speed of the grinding tool and the processing time in the lens grinding process.

BEST MODE FOR CARRYING OUT THE INVENTION

[0015] An embodiment of the lens spherical surface grinding method in which the present invention has been applied is described below with reference to the drawings.

(Spherical core-type lens grinding device)

[0016] FIG. 1 is a structural view showing an example of a spherical core-type lens grinding device for grinding a spherical surface lens using the method of the present invention. Spherical core-type lens grinding device 1 is provided with an upper unit 2 and a lower unit 3. The upper unit 2 is provided with a lens holder 4 in a downward-facing state. The lens holder 4 is installed on the lower end of a lens-pressurizing shaft 5, and it becomes possible to increase pressure downward using a pressurizing cylinder 6 in the direction of the unit center axial line 2a. The lens blank 7 to be ground can be held by a downward-facing lens holding surface 4a of the lens holder 4 in a rotatable state about the unit center axial line 2a. Also, the upper unit 2 can be moved in a relative manner in the direction closer to and farther away from the lower unit 3.

[0017] The lower unit 3 is provided with a dish-shaped grindstone 8 in a downward-facing state, and the dish-shaped grindstone 8 has a concave spherical grindstone surface 8a provided with diamond abrasive grains. The surface-to-be-ground 7a of the lens blank 7, which is held by the upper unit 2, is pressed against the spherical grindstone surface 8a. The dish-shaped grindstone 8 is fixed in a coaxial state to the upper end of a spindle shaft 9, and the spindle shaft 9 is rotatably driven about the center axial line 9a using a spindle motor 10. Also, the dish-shaped grindstone 8 and rotation mechanism (the spindle shaft 9, the spindle motor 10) are supported by a swinging mechanism 11. The swinging mechanism 11 is capable of causing the dish-shaped grindstone 8 to swing in a set swinging direction with a set swing angle θ and a set processing radius R about a swing center O in which the spherical grindstone surface 8a is positioned on the center axial line 2a.

[0018] Here, pressurization force from the pressurizing cylinder 6 can be switched in three stages using a first regulator 12, a second regulator 13, and a third regulator 14. A working fluid in which the pressure is set by the first through third regulators 12, 13, 14 is supplied to the pressurizing cylinder 6 via first through third switching valves 15, 16, 17, respectively, which can be switched on and off. Control for switching the pressurization force by a pressurizing mechanism with this configuration (lens pressurizing shaft 5, pressurizing cylinder 6, first through third regulators 12 through 14, and first through third switching valves 15 through 17) can be carried out by switching the first through third switching valves 15 through 17.

[0019] Next, a controller 18 drives and controls each part, and control for switching the first through third switching valves 15 through 17 of the pressurizing mechanism is carried out by the controller 18. Also, the controller 18 monitors the amount of grinding of the lens blank 7 on the basis of the measurement results of a measurement device 19, controls the switching of the switch valves 15 through 17 in accordance with the amount of grinding, and switches the processing pressure for pressing the surface-to-be-ground 7a of the lens blank 7 against the spherical grindstone surface 8a of the dish-shaped grindstone 8. Controller 18 drives and controls the spindle motor 10 via an inverter 20 and controls the rotational speed of the dish-shaped grindstone 8. Controller 18 drives and controls of the swinging mechanism 11 via an inverter 21, and changes the swing direction of the dish-shaped grindstone 8, the switching control of the swing angle θ, the swing position, and the like.

(Example of the grinding operation)

[0020] FIG. 2 is a general flowchart showing the spherical surface lens grinding operation using the spherical core-type lens grinding device 1. Described with reference to FIGS. 1 and 2, first, the lens blank 7 is installed on the lens holding surface 4a of the lens holder 4, and forms a state in which the surface-to-be-ground 7a of the lens blank 7 is pressed against the spherical grindstone surface 8a of the dish-shaped grindstone 8 (lens blank supply process ST1).

[0021] In this state, the rotation and swinging of the dish-shaped grindstone 8 is started, and the grinding of the surface-to-be-ground 7a of the lens blank 7 is started. In the initial-stage grinding process ST2, which is from the starting point of the grinding until a predetermined amount of time passes, grinding is carried out in a state in which the lens blank 7 is pressed against the dish-shaped grindstone 8 under a processing pressure that is set by the first regulator 12. The processing pressure is preferably kept to a minimum at which the lens blank 7 does not fall from between the lens holder 4 and the dish-shaped grindstone 8, and is less than the processing pressure of the intermediate-stage grinding process, which is the next process, because the area of contact between the lens blank 7 and the dish-shaped grindstone 8 is small. Also, it is preferred that the rotational speed of the dish-shaped grindstone 8 in the initial-stage grinding process be low, and 400 to 600 rpm is preferred in terms of balance with the processing time. This rotational speed is also slower than the rotational speed in the intermediate-stage grinding process, which is the next process.

[0022] In the initial-stage grinding process ST2, the grinding of the surface-to-be-ground 7a of the lens blank 7 is advanced, and when a state is formed in which said surface-to-be-ground 7a is substantially in contact with the spherical grindstone surface 8a of the dish-shaped grindstone 8, the processing pressure is switched to a processing pressure that is set by the second regulator 13. The grinding thereby proceeds to the intermediate-stage grinding process S3.

[0023] The processing pressure in the intermediate-stage grinding process ST3 is a pressure at which the abrasive grains of the dish-shaped grindstone 8 (diamond bite) can bite into the lens blank 7. It is preferred that the processing pressure be set at or near the minimum value of the pressure at which the abrasive grains can bite into the lens blank 7. The desired surface coarseness for the spherical surface lens grinding is generally 4 μm. Consequently, the processing pressure that is applied to the lens blank 7 in the intermediate-stage grinding process can be calculated based on the biting amount of the dish-shaped grindstone 8 obtained from the hardness of said lens blank 7 and the contact area between the surface-to-be-ground 7a and the spherical grindstone surface 8a of the dish-shaped grindstone 8.

[0024] Also, the rotational speed of the dish-shaped grindstone 8 in the intermediate-stage grinding process is set to a rotational speed at which the abrasive grains of the dish-shaped grindstone 8 (diamond bite) can bite into the lens blank 7. A rotational speed that allows the abrasive grains to bite into the lens blank 7 refers to a rotational speed that is equal or less than the maximum rotational speed at which the change in processing time substantially disappears in the case that the rotational speed of the dish-shaped grindstone has been changed at the processing pressure set in the manner described above. In other words, at a rotational speed greater than the maximum rotational speed, the processing time is not shortened, and slipping occurs between the spherical grindstone surface of the dish-shaped grindstone and the surface-to-be-ground of the lens blank, resulting in a state in which the abrasive grains cannot bite into the surface of the lens blank. It is preferred that the rotational speed be set at or near the maximum value at which the abrasive grains can bite into the lens blank 7.

[0025] The grinding in intermediate-stage grinding process is advanced, and the processing pressure is switched to a processing pressure set by the third regulator 14 at the state where the center thickness of the lens blank 7 reaches a value just prior to the target thickness. The grinding thereby proceeds to the last-stage grinding process ST4.

[0026] In the last-stage grinding process, the progression rate of the grinding is slowed (the rotational speed of the dish-shaped grindstone 8 is reduced), and he grinding is carried out in a state in which the variability does not occur in the center thickness of the lens blank 7, so that the target coarseness of the surface-to-be-ground 7a is reached. In the last-stage grinding process, the processing pressure is set at a pressure that is even lower than the processing pressure in the initial-stage grinding process, and the rotational speed of the dish-shaped grindstone 8 is set at a value that is lower than the rotational speed in the intermediate-stage grinding process and higher than the rotational speed in the initial-stage grinding process.

[0027] Here, spherical surface grinding which uses the dish-shaped grindstone is a cutting process by a diamond bite having a plurality of blade edges. Consequently, the processing pressure and the rotational speed of the dish-shaped grindstone as grinding conditions can be set in accordance with the hardness of the lens blank. In other words, the processing pressure can be set in proportion to the hardness of the lens blank and the rotational speed can be set inversely proportional to the hardness of the lens blank. The hardness data of the lens blank can easily be obtained in a materials catalog or the like, and an optimum processing pressure and rotational speed can therefore be obtained on the basis of the data.

[0028] Next, when the portion of the spherical grindstone surface 8a of the dish-shaped grindstone 8 that grinds the surface-to-be-ground 7a of the lens blank 7 is constantly the same, the grinding surface wears unevenly and the grinding shape is changed. Consequently, it is preferred that the position where the spherical grindstone surface 8a makes contact with the surface-to-be-ground 7a of the lens blank 7 (the slipping region of the surface-to-be-ground 7a on the spherical grindstone surface 8a) be periodically changed to prevent uneven wearing of the spherical grindstone surface 8a and to keep the grinding precision constant so that the entire surface is uniformly worn. It is preferred that such changes be made at least in the intermediate-stage grinding process.

[0029] As described above, in the present embodiment, the processing pressure and the rotational speed are reduced in the initial processing stage, whereby the lens blank to be processed can be prevented from chipping and cracking.

In the intermediate processing stage, the processing pressure is increased and the rotational speed is switched to high speed in comparison with the initial processing stage, whereby the processing time can be shortened. In the last processing stage, the pressure is reduced in comparison with the initial processing stage and the rotational speed is set at a moderate speed that is faster than that in the initial processing stage and slower than that in the intermediate processing stage, whereby the precision of the center thickness of the lens blank can be ensured. Thus, the grinding conditions are changed in multiple stages in conjunction with the progress of grinding, whereby a high precision grinding surface can be formed on the lens blank using only the dish-shaped grindstone.

(Experimental Example)

[0030] The present inventors carried out the manufacturing in the following manner using the grinding method of the present invention.
The processing data for the present experimental example are as follows:

Lens blank material	TAFD25
Degree of wear of the lens blank	90
Knoop hardness of the lens blank	630
Processing spherical surface radius R	108 mm
Lens outside diameter	37.5 mm
Dish-shaped grindstone	Diamond pellet SP60B #800

[0031] First, a test was carried out to determine the processing pressure. The test conditions are as follows, and the test results are shown in the table and graph of FIG. 3.
[0032]

Spherical core-type grinding device: NC Grinder Model PM50
(Manufacturer: Kojima Engineering, Ltd.)
Rotational speed of the dish-shaped grindstone: 1,000 rpm
Lens contact area on the dish-shaped grindstone: 4.52 cm^2
Processing distance: 0.1 mm

[0033] It is apparent from these test results that the wear amount of the lens blank is substantially unchanged when the processing pressure is 10 kg/cm^2 or greater, and this pressure is therefore the maximum point for grinding efficiency.
[0034] Next, a test was carried out to determine the rotational speed of the dish-shaped grindstone using the same spherical core-type grinding device, and the processing time when the rotational speed was varied was examined for the cases of a processing pressure 1 (15 kg/cm^2) and a processing pressure 2 (10 kg/cm^2). The test conditions are the same as the cases described above except for the processing pressure. The test results are shown in a graph in FIG. 4.
[0035] It is apparent from these test results that the wear amount is substantially unchanged when the rotational speed approaches 1,500 rpm, and this point is therefore the maximum point for processing efficiency. In other words, with the processing pressure being fixed, the rotational speed at which the change in the processing time substantially disappears in the case that the rotational speed is increased is the maximum value of "the rotational speed that allows the abrasive grains to bite into the lens blank." When the rotational speed is increased further, slipping occurs between the lens blank and the dish-shaped grindstone, resulting in a state in which the abrasive grains on the dish-shaped grindstone cannot bite into the surface of the lens blank. This maximum value of "the rotational speed that allows the abrasive grains to bite into the lens blank" is the maximum point for processing efficiency. This maximum value can be set by experimentation because the maximum value varies in accordance with the hardness of the lens blank, the granularity of the abrasive grains of the dish-shaped grindstone, the performance of the cutting fluid, and the like.
[0036] On the basis of these test results, it is apparent that a processing pressure of 10 kg/cm^2 and a dish-shaped grindstone rotational speed of 1,500 rpm are optimal as the processing conditions in the intermediate-stage grinding process ST3. The processing conditions in the initial-stage grinding process ST2 and the last-stage grinding process ST4 are each set with reference to these parameters.
[0037] In the experiment of the present inventors, grinding was carried out for 10 seconds in the initial-stage grinding process with a processing pressure of 2 kg/cm^2 and a rotational speed of 500 rpm. Next, the experiment proceeded to the intermediate-stage grinding process, and grinding was carried out with a processing pressure of 10 kg/cm^2 and a rotational speed of 1,500 rpm until just prior to the lens blank reaching the target thickness of 0.1 mm. Next, the experiment proceeded to the last-stage grinding process, and grinding was carried out with a processing pressure of 1.5 kg/cm^2 and a rotational speed of 1,000 rpm until the lens blank reached the target thickness.

[0038] As a result, the thickness precision was confirmed to be within ±0.005 μm. Also, the curvature of the grinding surface was measured, and after 150 cycles, ΔH changed by -0.001 μm. The swing position was shifted 10% and subjected to 150 more cycles, after which the ΔH returned to the reference value, and the swing position was therefore returned to the original position. By these continuations, the curvature of the grinding surface was confirmed to be within a range of 0 to 0.001 μm in terms of ΔH.

[Key]

[0039]

1:	Spherical core-type lens grinding device
2:	Upper unit
2a:	Center axial line
3:	Lower unit
4:	Lens holder
4a:	Lens holder surface
5:	Lens pressurizing shaft
6:	Pressurizing cylinder
7:	Lens blank
7a:	Surface-to-be-ground
8:	Dish-shaped grindstone
8a:	Spherical grindstone surface
9:	Spindle shaft
9a:	Center axial line
10:	Spindle motor
11:	Swinging mechanism
12, 13, 14:	Regulator
15, 16, 17:	Switching valve
18:	Controller
19:	Measurement device
20:	Inverter
21:	Driver
O:	Swing center
θ:	Swing angle

R: Processing radius of the spherical surface

Claims

1. A lens spherical surface grinding method using a dish-shaped grindstone in which a dish-shaped grindstone provided with a spherical grindstone surface provided with diamond abrasive grains is pressed at a predetermined pressure against a surface-to-be-ground of a grinding target lens blank, and in such a state, the surface-to-be-ground is ground on a spherical surface while the dish-shaped grindstone is rotated and swung at a predetermined rotational speed,
the method **characterized in** comprising:

   an initial-stage grinding process for performing grinding in which the processing pressure is a first processing pressure and the rotational speed is a first rotational speed;
   an intermediate-stage grinding process for performing grinding in which the processing pressure is a second processing pressure and the rotational speed is a second rotational speed; and
   a last-stage grinding process for performing grinding in which the processing pressure is a third processing pressure and the rotational speed is a third rotational speed, wherein
   the second processing pressure is a pressure at which the spherical grindstone surface can bite into the lens blank, a biting amount of the dish-shaped grindstone is obtained from a hardness of the lens blank and a contact area between the surface-to-be-ground of the lens blank and the spherical grindstone surface of the dish-shaped grindstone, and the second processing pressure is calculated on the basis of the biting amount;
   the second rotational speed is set to a rotational speed at which the diamond abrasive grains of the dish-shaped grindstone can bite into the lens blank;
   the first processing pressure is set to a value less than the second processing pressure and the first rotational speed is set to a value less than the second rotational speed; and
   the third processing pressure is set to a value less than the first processing pressure and the third rotational speed is set to a value less than the second rotational speed and greater than the first rotational speed.

2. The lens spherical surface grinding method using a dish-shaped grindstone according to claim 1, **characterized in that**
the second processing pressure is set to a minimum value at which the diamond abrasive grains of the dish-shaped grindstone can bite into the lens blank; and
the second rotational speed is set at a maximum value at which the diamond grains of the dish-shaped grindstone can bite into the lens blank.

3. The lens spherical surface grinding method using a dish-shaped grindstone according to claim 1 or 2, **characterized in that** the initial-stage grinding process is carried out until a state is formed in which the surface-to-be-ground of the lens blank is in contact with the entire spherical grindstone surface; and
the intermediate-stage grinding process is carried out until a state is formed in which a center thickness of the lens blank is greater than a target value by a dimension set in advance.

4. The lens spherical surface grinding method using a dish-shaped grindstone according to any of claims 1 through 3, **characterized in that** a region in which the surface-to-be-ground of the lens blank slides on the spherical grindstone surface of the dish-shaped grindstone is periodically changed in at least the intermediate-stage grinding process.

5. The lens spherical surface grinding method using a dish-shaped grindstone according to any of claims 1 through 4, **characterized in that**:

   the hardness of the lens blank has a Knoop hardness of 630;
   the second processing pressure is 10 kg/cm^2 and the second rotational speed is 1,500 rpm;
   the first processing pressure is 2 kg/cm^2 and the first rotational speed is 400 to 600 rpm; and
   the third processing pressure is 1.5 kg/cm^2 and the third rotational speed is 1,000 rpm.

6. A spherical core-type lens grinding device comprising:

   a lens holder for holding a lens blank;
   a dish-shaped grindstone provided with a spherical grindstone surface against which a surface-to-be-ground

of a lens blank held in the lens holder is pressed;
a pressurizing mechanism with which a first processing pressure, a second processing pressure, and a third processing pressure can be selectively applied as the pressure for pressing the lens blank against the spherical grindstone surface;
a rotation mechanism for causing the disc-shaped grindstone to rotate;
a swinging mechanism for causing the dish-shaped grindstone to swing; and
a controller for controlling the driving of the pressurizing mechanism, the rotation mechanism, and the swinging mechanism, and causing the grinding method according to any of claims 1 through 5 to be executed.

Amended claims under Art. 19.1 PCT

1. A lens spherical surface grinding method using a dish-shaped grindstone in which a dish-shaped grindstone provided with a spherical grindstone surface provided with diamond abrasive grains is pressed at a predetermined pressure against a surface-to-be-ground of a grinding target lens blank, and in such a state, the surface-to-be-ground is ground on a spherical surface while the dish-shaped grindstone is rotated and swung at a predetermined rotational speed,
the method **characterized in** comprising:

an initial-stage grinding process for performing grinding in which the processing pressure is a first processing pressure and the rotational speed is a first rotational speed;
an intermediate-stage grinding process for performing grinding in which the processing pressure is a second processing pressure and the rotational speed is a second rotational speed; and
a last-stage grinding process for performing grinding in which the processing pressure is a third processing pressure and the rotational speed is a third rotational speed, wherein
the second processing pressure is a pressure at which the spherical grindstone surface can bite into the lens blank, a biting amount of the dish-shaped grindstone is obtained from a hardness of the lens blank and a contact area between the surface-to-be-ground of the lens blank and the spherical grindstone surface of the dish-shaped grindstone, and the second processing pressure is calculated on the basis of the biting amount;
the second rotational speed is set to a rotational speed at which the diamond abrasive grains of the dish-shaped grindstone can bite into the lens blank;
the first processing pressure is set to a value less than the second processing pressure and the first rotational speed is set to a value less than the second rotational speed; and
the third processing pressure is set to a value less than the first processing pressure and the third rotational speed is set to a value less than the second rotational speed and greater than the first rotational speed.

2. The lens spherical surface grinding method using a dish-shaped grindstone according to claim 1, **characterized in that**
the second processing pressure is set to a minimum value at which the diamond abrasive grains of the dish-shaped grindstone can bite into the lens blank; and
the second rotational speed is set at a maximum value at which the diamond grains of the dish-shaped grindstone can bite into the lens blank.

3. The lens spherical surface grinding method using a dish-shaped grindstone according to claim 1 or 2, **characterized in that** the initial-stage grinding process is carried out until a state is formed in which the surface-to-be-ground of the lens blank is in contact with the entire spherical grindstone surface; and
the intermediate-stage grinding process is carried out until a state is formed in which a center thickness of the lens blank is greater than a target value by a dimension set in advance.

4. The lens spherical surface grinding method using a dish-shaped grindstone according to any of claims 1 through 3, **characterized in that** a region in which the surface-to-be-ground of the lens blank slides on the spherical grindstone surface of the dish-shaped grindstone is periodically changed in at least the intermediate-stage grinding process.

5. The lens spherical surface grinding method using a dish-shaped grindstone according to any of claims 1 through 4, **characterized in that**:

the hardness of the lens blank has a Knoop hardness of 630;
the second processing pressure is 10 kg/cm^2 and the second rotational speed is 1,500 rpm;

the first processing pressure is 2 kg/cm^2 and the first rotational speed is 400 to 600 rpm; and the third processing pressure is 1.5 kg/cm^2 and the third rotational speed is 1,000 rpm.

6. Cancelled)

FIG.1

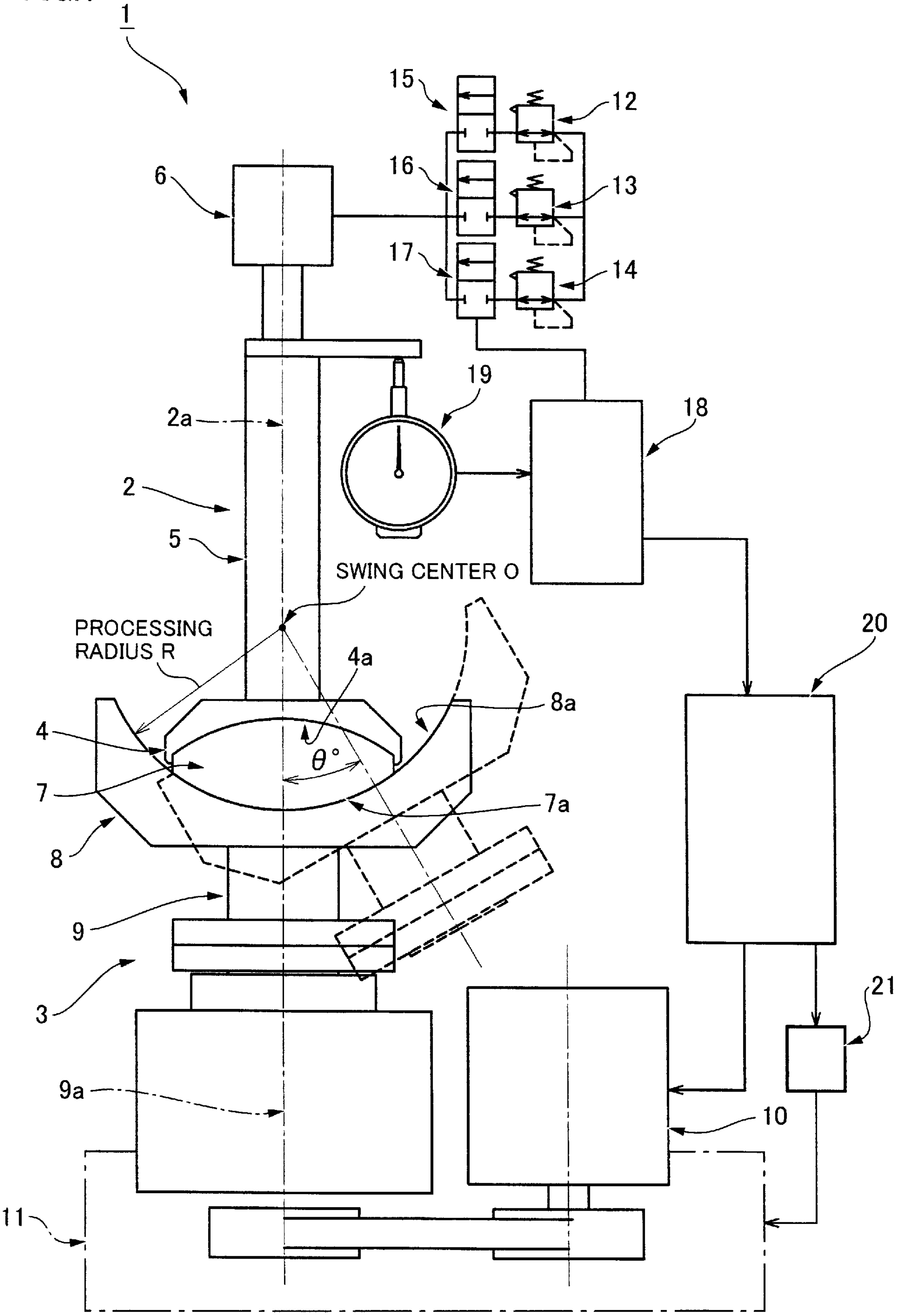

1
15
12
16
13
6
17
14
19
2a
18
2
5
SWING CENTER O
20
PROCESSING
RADIUS R
4a
8a
4
θ°
7
7a
8
9
3
21
9a
10
11

FIG.2

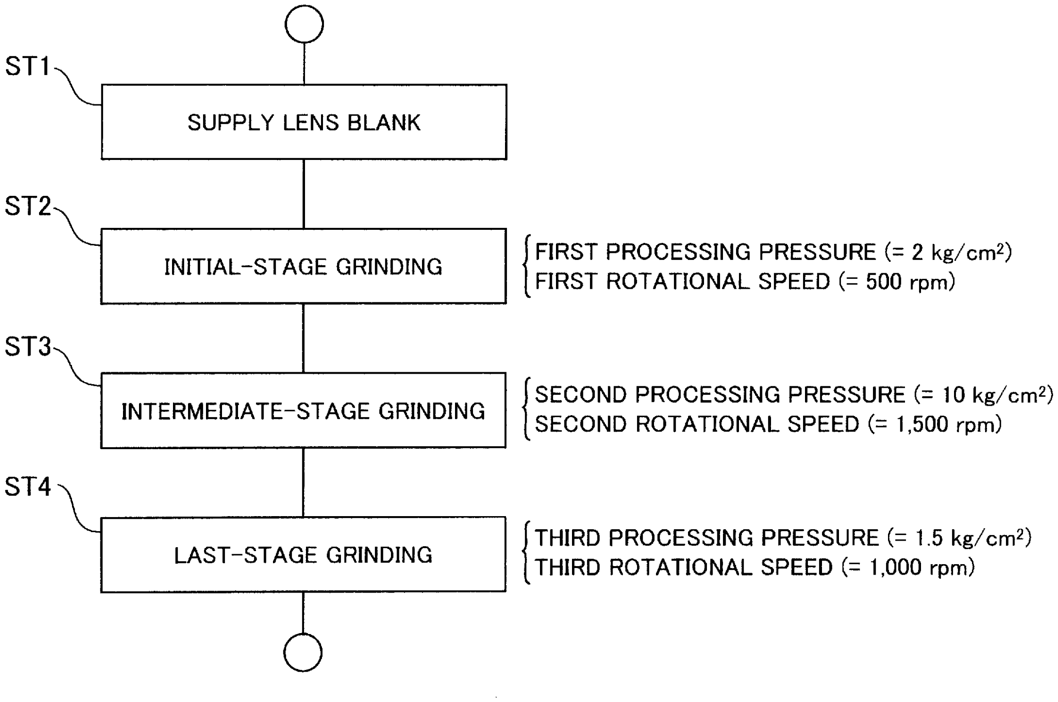

ST1
SUPPLY LENS BLANK
ST2
INITIAL-STAGE GRINDING
FIRST PROCESSING PRESSURE (= 2 kg/cm2)
FIRST ROTATIONAL SPEED (= 500 rpm)
ST3
INTERMEDIATE-STAGE GRINDING
SECOND PROCESSING PRESSURE (= 10 kg/cm2)
SECOND ROTATIONAL SPEED (= 1,500 rpm)
ST4
LAST-STAGE GRINDING
THIRD PROCESSING PRESSURE (= 1.5 kg/cm2)
THIRD ROTATIONAL SPEED (= 1,000 rpm)

FIG.3

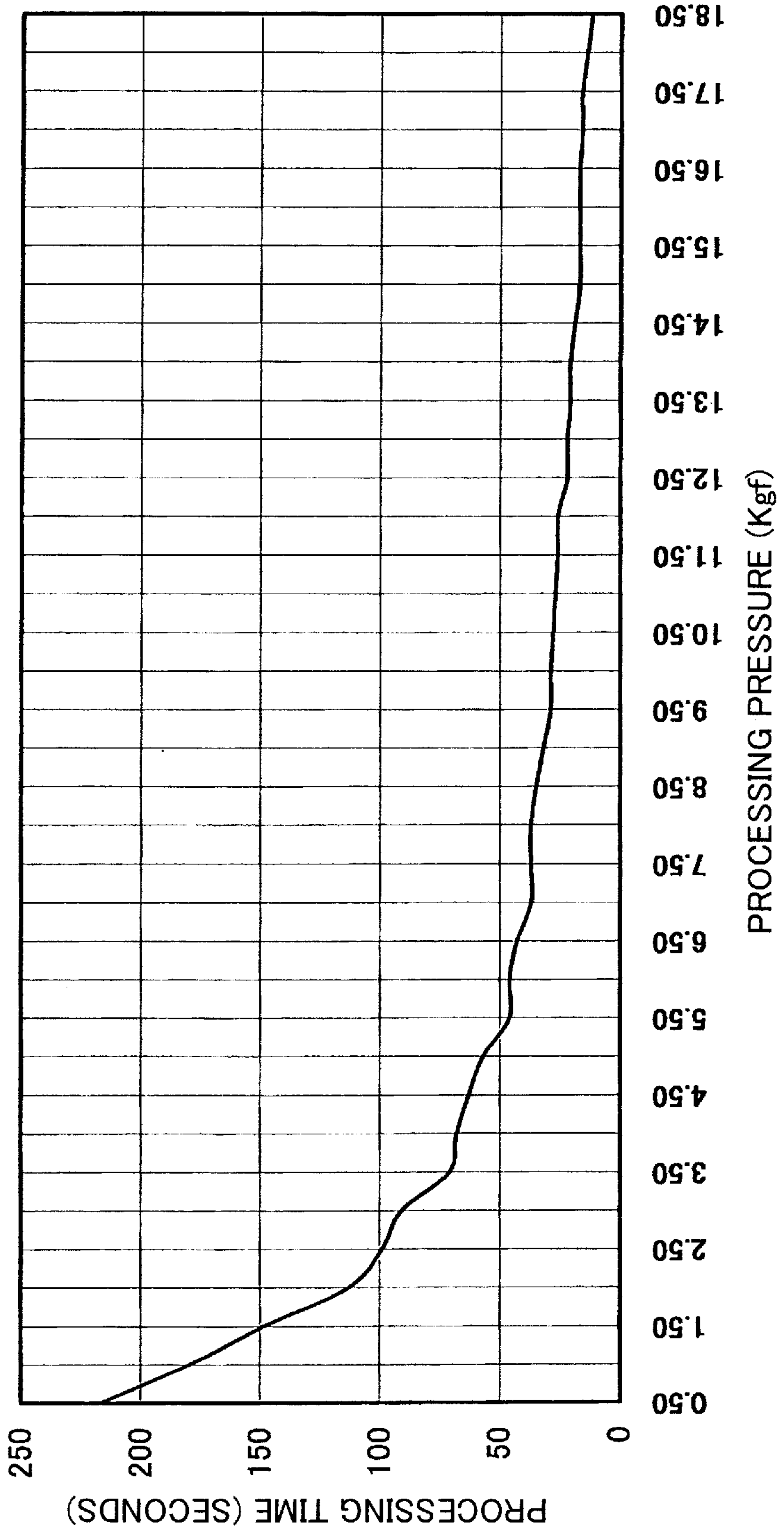
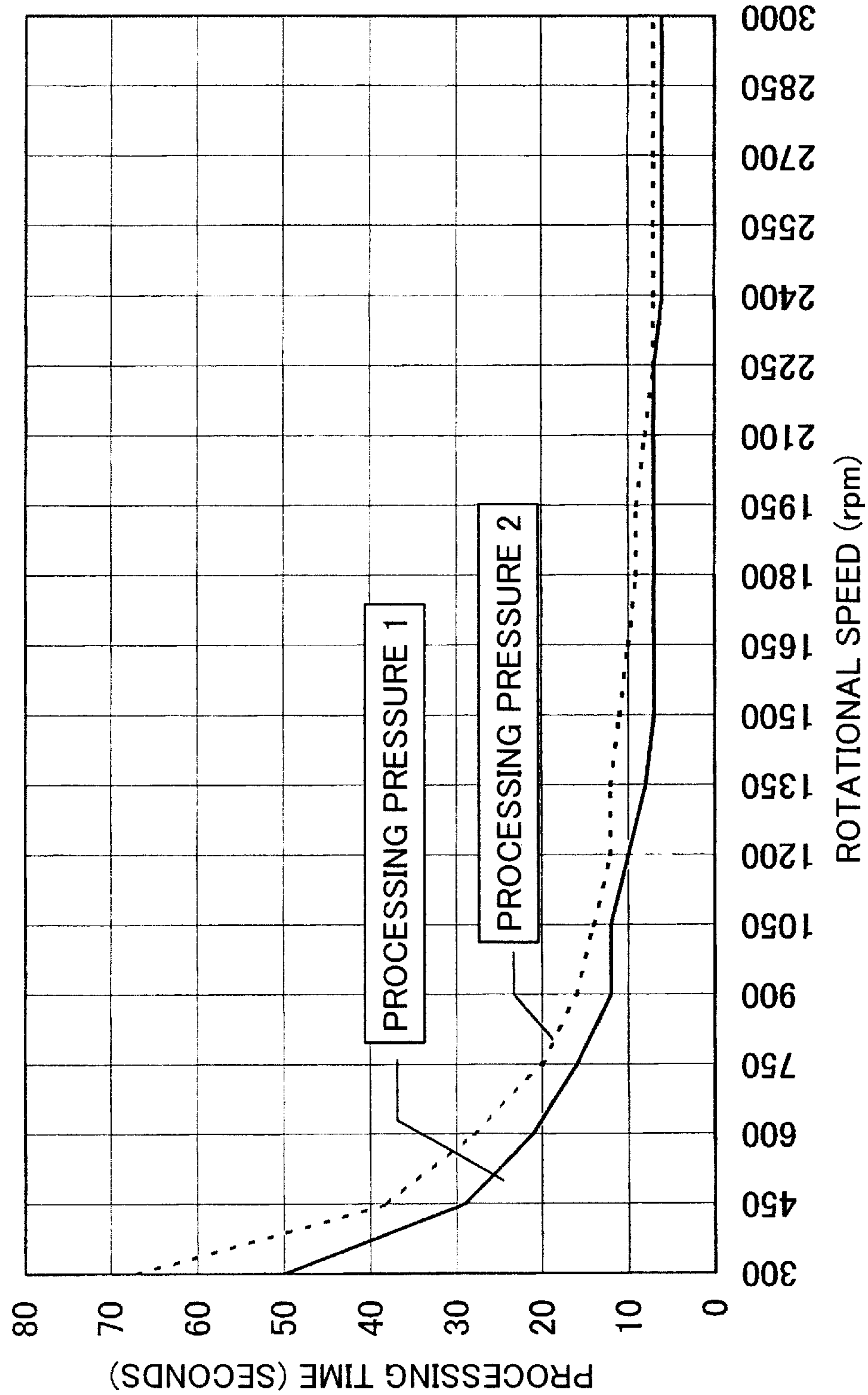

PROCESSING TIME (SECONDS)
250
200
150
100
50
0
PROCESSING PRESSURE (Kgf)
0.50
1.50
2.50
3.50
4.50
5.50
6.50
7.50
8.50
9.50
10.50
11.50
12.50
13.50
14.50
15.50
16.50
17.50
18.50

FIG.4


PROCESSING TIME (SECONDS)
0
10
20
30
40
50
60
70
80
ROTATIONAL SPEED (rpm)
300
450
600
750
900
1050
1200
1350
1500
1650
1800
1950
2100
2250
2400
2550
2700
2850
3000
PROCESSING PRESSURE 1
PROCESSING PRESSURE 2

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2010/000563

A. CLASSIFICATION OF SUBJECT MATTER
B24B13/04(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
B24B13/04

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Jitsuyo Shinan Koho	1922-1996	Jitsuyo Shinan Toroku Koho	1996-2010
Kokai Jitsuyo Shinan Koho	1971-2010	Toroku Jitsuyo Shinan Koho	1994-2010

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X A	JP 2008-260091 A (Olympus Corp.), 30 October 2008 (30.10.2008), entire text; all drawings (Family: none)	6 1-5
X A	JP 4-125558 U (Canon Inc.), 16 November 1992 (16.11.1992), entire text; all drawings (Family: none)	6 1-5
A	JP 8-197425 A (Olympus Optical Co., Ltd.), 06 August 1996 (06.08.1996), entire text; all drawings (Family: none)	1-6

☒ Further documents are listed in the continuation of Box C. ☐ See patent family annex.

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
16 February, 2010 (16.02.10)	02 March, 2010 (02.03.10)

Name and mailing address of the ISA/	Authorized officer
Japanese Patent Office	
Facsimile No.	Telephone No.

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2010/000563

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	JP 2004-338028 A (Nikon Corp.), 02 December 2004 (02.12.2004), entire text; all drawings (Family: none)	1-6

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REFERENCES CITED IN THE DESCRIPTION

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Patent documents cited in the description

- JP 2006297520 A **[0004]**
- JP 2009066724 A **[0004]**
- JP 2009090414 A **[0004]**