

DESCRIPTION

TITLE OF THE INVENTION

METHOD FOR MACHINING GLASS PLATE, MACHINING
DEVICE FOR MACHINING GLASS PLATE, AND METHOD FOR
MANUFACTURING EUVL-USE MASK BLANK

TECHNICAL FIELD

[0001]

The present disclosure relates to a method for machining a glass plate, a machining device for machining the glass plate, and a method for manufacturing an EUVL-use mask blank.

BACKGROUND ART

[0002]

Conventionally, a photolithographic technique is used to make semiconductor devices. With photolithographic techniques, an exposure device irradiates a photomask pattern with light and transfers the photomask pattern onto a resist film.

[0003]

Nowadays, the use of short-wavelength exposure light, such as ArF excimer laser light, and moreover, EUV (Extreme Ultra-Violet) light, is being investigated to enable the transfer of fine patterns.

[0004]

Here, EUV light includes soft X-rays and vacuum ultraviolet light, specifically, light with a wavelength of about 0.2 nm to 100 nm. At present, EUV light having a wavelength of about 13.5 nm is predominately being investigated as the exposure light.

[0005]

Patent Document 1 describes a method for manufacturing an for Extreme Ultra-Violet Lithography (EUVL)-use mask blank. The mask blank for EUVL includes a glass plate, a reflective film formed on the glass plate, and an absorption film formed on the reflective film.

[0006]

EUVL-use mask blanks having a high degree of flatness to improve the transfer accuracy of fine patterns are in demand. The degree of flatness of the mask blank for EUVL is determined predominately by the degree of flatness of the glass plate serving as the substrate, and thus glass plates having a high degree flatness are in demand.

[0007]

The manufacturing method described in Patent Document 1 has a preliminary polishing step, a measuring step, and a modified polishing step. In the preliminary polishing

step, both main surfaces of the glass plate are preliminarily polished. In the measuring step, the maximum thickness distribution and degree of flatness of the glass plate are measured. In the modified polishing step, a main surface of the glass plate is locally polished based on the measurement results of the measuring step.

CITATION LIST

PATENT LITERATURE

[0008]

Patent Document 1: International Publication No. 2011/115131

SUMMARY OF THE INVENTION

PROBLEMS TO BE SOLVED BY THE INVENTION

[0009]

In Patent Document 1, a gas cluster or the like is used for the local polishing. The gas cluster is ionized by the collision of thermal electrons and then accelerated by an electric field and emitted towards the first main surface of the glass plate, thereby etching the first main surface locally. As a result, the first main surface can be flattened.

[0010]

Incidentally, the gas cluster impacts not only the first main surface of the glass plate but also peripheral components surrounding the glass plate. The collision sometimes results in defects on the second main surface opposite to the first main surface and one of the end surfaces of the glass plate.

[0011]

Defects are caused, for example, by flying debris. The flying debris are gas clusters that have changed directions due to collisions with peripheral components, or are particles that get projected from the peripheral components due to collisions between gas clusters and the peripheral components. The materials of the particles are the same as those of the peripheral components.

[0012]

Defects can also be caused by direct collision of gas clusters. For example, in a case where the first main surface of the glass plate is inclined with respect to the irradiation direction of the gas cluster, the gas cluster also directly collides with the end surface of the glass plate.

[0013]

Hereinafter, the gas clusters and the flying debris produced by the collision of gas cluster with the peripheral components are the cause of the defects and are

collectively referred to as fluid matter.

[0014]

One aspect of the present disclosure provides a technique that can suppress an occurrence of defects on a glass plate due to the emission of a gas cluster.

MEANS FOR SOLVING THE PROBLEM

[0015]

A method for machining a glass plate according to one aspect of the present disclosure includes irradiating a first main surface of the glass plate with a beam-shaped gas cluster; moving the glass plate such that a point at which the first main surface of the glass plate is irradiated with the gas cluster is moved; and blocking fluid matter that is expected to form a defect on at least one of a second main surface of the glass plate and an end surface of the glass plate by using a blocking unit that moves together with the glass plate, the second main surface being opposite to the first main surface.

EFFECT OF THE INVENTION

[0016]

According to one aspect of the present disclosure, an occurrence of defects on the glass plate due to the emission of the gas cluster can be suppressed.

BRIEF DESCRIPTION OF DRAWINGS

[0017]

FIG. 1: FIG. 1 is a flowchart illustrating a method for manufacturing an EUVL-use mask blank according to an embodiment;

FIG. 2: FIG. 2 is a cross-sectional view illustrating an example of a glass plate provided in S1 of FIG. 1;

FIG. 3: FIG. 3 is a plan view illustrating an example of the glass plate of FIG. 2;

FIG. 4: FIG. 4 is a cross-sectional view illustrating a mask blank for an EUVL according to an embodiment;

FIG. 5: FIG. 5 is a cross-sectional view illustrating an example of an EUVL-use photomask;

FIG. 6: FIG. 6 is a cross-sectional view illustrating a machining device according to an embodiment;

FIG. 7: FIG. 7 is a cross-sectional view illustrating an enlarged view of the glass plate, peripheral components of the glass plate, and a shield plate of FIG. 6;

FIG. 8: FIG. 8 illustrates the glass plate and peripheral components of the glass plate as seen through the shield plate of FIG. 7 in the irradiation direction of the gas cluster of FIG. 7;

FIG. 9: FIG. 9 is a view of clamps and spacers of FIG. 7

in another direction;

FIG. 10: FIG. 10 is a view of a stage according to a modified example in the irradiation direction of the gas cluster;

FIG. 11: FIG. 11 is a cross-sectional view illustrating a blocking unit according to the modified example; and

FIG. 12: FIG. 12 is a cross-sectional view illustrating the blocking unit according to another modified example.

MODE FOR CARRYING OUT THE INVENTION

[0018]

Embodiments of the present disclosure are described below with reference to the drawings. Identical or corresponding configurations in each drawing are designated by the same reference numerals and duplicate descriptions may be omitted. In the description, the word "to" indicating a numerical range means that the numerical range includes the numerical values mentioned before and after the word "to" as the lower limit value and the upper limit value.

[0019]

As illustrated in FIG. 1, a method for manufacturing an Extreme Ultra-Violet Lithography (EUVL)-use mask blank includes S1 to S7. Glass plates are used to manufacture mask blanks. Glass of the glass plate is preferably quartz glass containing 90% by mass or more of SiO_2 . The upper limit of SiO_2 content in quartz glass is 100% by mass. Quartz glass has a smaller coefficient of linear expansion and smaller dimensional change caused by temperature change than typical soda-lime glass. The quartz glass may contain TiO_2 in addition to SiO_2 . The quartz glass may contain 90% by mass to 95% by mass of SiO_2 and may contain 5% by mass to 10% by mass of TiO_2 . When the TiO_2 content is 5% by mass to 10% by mass, the coefficient of linear expansion near room temperature is almost zero, and there is little dimensional change around room temperature. The quartz glass may contain a trace component other than SiO_2 and TiO_2 , but it is preferable not to contain a trace component.

[0020]

The glass plate 2 includes a first main surface 21, a second main surface 22, four end surfaces 23, four first chamfered surfaces 24, and four second chamfered surfaces 25, as illustrated in FIGS. 2 and 3. The first main surface 21 is rectangular in shape. In this specification, the rectangular shape includes a shape with chamfered corners. The rectangle includes a square. The second main surface 22 is opposite to the first main surface 21. The second main surface 22 is rectangular as is the first main

surface 21. The end surfaces 23 are perpendicular to the first main surface 21 and the second main surface 22. The first chamfered surface 24 is formed at the border of the first main surface 21 and the end surface 23. The second chamfered surfaces 25 are formed at the border of the second main surface 22 and the end surface 23. The first chamfered surfaces 24 and the second chamfered surfaces 25 are what is known as C-chamfered surfaces in this embodiment, but they may be R-chamfered surfaces.

[0021]

The first main surface 21 of the glass plate 2 has a quality assurance region 26 indicated by a dotted pattern in FIG. 3. The quality assurance region 26 is the region that is machined to the desired flatness by S1 to S4. The quality assurance region 26 is a region excluding a peripheral edge region 27 where, for example, the distance L from the end surface 23 is within 5 mm as seen in a direction perpendicular to the first main surface 21. Although not illustrated, the second main surface 22 of the glass plate 2 also has a quality assurance region and a peripheral edge region, as does the first main surface 21.

[0022]

First, in S1 of FIG. 1, the first main surface 21 and the second main surface 22 of the glass plate 2 are polished. The first main surface 21 and the second main surface 22 may be polished at the same time with a double-side grinder or in sequence with a single-side grinder. In S1, the glass plate 2 is polished while the polishing slurry is supplied to between the polishing pad and the glass plate 2. The polishing slurry contains an abrasive. The abrasive is, for example, cerium oxide particles. The first main surface 21 and the second main surface 22 may be polished multiple times with abrasives of different materials or of different particle sizes.

[0023]

The abrasive used in S1 is not limited to cerium oxide particles. For example, the abrasive used in S1 may be silicon oxide particles, aluminum oxide particles, zirconium oxide particles, titanium oxide particles, diamond particles, silicon carbide particles, or the like.

[0024]

Next, in S2 of FIG. 1, surface geometries of the first main surface 21 and the second main surface 22 of the glass plate 2 are measured. For example, a non-contact measuring apparatus, such as a laser interference type apparatus, is used to measure the surface geometries, so as to prevent the surfaces from becoming damaged. The measuring machine measures the surface geometries of the quality assurance region 26 of the first main surface 21 and the quality

assurance region of the second main surface 22.

[0025]

Next, in S3 of FIG. 1, referring to the measurement result of S2, the first main surface 21 and the second main surface 22 of the glass plate 2 are machined with a beam-shaped gas cluster to improve the degree of flatness. The first main surface 21 and the second main surface 22 are etched with the gas cluster in sequence. The sequence can be whichever is meant to come first, and as such, is not particularly limited.

[0026]

The gas clusters are ionized by the collision of thermal electrons, then accelerated by an electric field, and after further neutralization, are emitted towards the first main surface 21 or the second main surface 22. The bombardment of the gas clusters causes the first main surface 21 or the second main surface 22 to be locally etched and flattened. The details of S3 are described in detail further below.

[0027]

Next, in S4 of FIG. 1, final polishing of the first main surface 21 and the second main surface 22 of the glass plate 2 is performed. The first main surface 21 and the second main surface 22 may be polished at the same time with a double-side grinder or in sequence with a single-side grinder. In S4, the glass plate 2 is polished while the polishing slurry is supplied to between the polishing pad and the glass plate 2. The polishing slurry contains an abrasive. The abrasive is, for example, colloidal silica particles.

[0028]

Next, in S5 of FIG. 1, the reflective film 3 illustrated in FIG. 4 is formed in the quality assurance region 26 of the first main surface 21 of the glass plate 2. The reflective film 3 reflects EUV light. The reflective film 3 may be, for example, a multilayer reflective film in which a high refractive index layer and a low refractive index layer are alternately stacked. The high-index layer is formed, for example, of silicon (Si), whereas the low-index layer is formed, for example, of molybdenum (Mo). A sputtering method such as ion beam sputtering or magnetron sputtering is used as a film formation method of the reflective film 3.

[0029]

Next, in S6 of FIG. 1, an absorption film 4 illustrated in FIG. 4 is formed on the reflective film 3 formed in S5. The absorption film 4 absorbs EUV light. The absorption film 4 is formed of a single metal, an alloy, a nitride, an oxide, or an oxynitride, or the like, or any

combination thereof. The single metal contains at least one element selected from, for example, tantalum (Ta), chromium (Cr), and palladium (Pd). For example, a sputtering method is used as a method for forming the absorption film 4.

[0030]

Lastly, in S7 of FIG. 1, a conductive film 5 illustrated in FIG. 4 is formed in the quality assurance region of the second main surface 22 of the glass plate 2. The conductive film 5 is used to cause a photomask to be attracted by an electrostatic chuck of an exposure apparatus. The conductive film 5 is formed of, for example, chromium nitride (CrN). A sputtering method, for example, is used as a method for forming the conductive film 5. Although S7 is performed after S5 and S6 in this embodiment, S7 may be performed before S5 and S6.

[0031]

The arrangement of the reflective film 3 and the conductive film 5 may be reversed. That is, the conductive film 5 may be formed in the quality assurance region 26 of the first main surface 21 of the glass plate 2, and the reflective film 3 may be formed in the quality assurance region of the second main surface 22 of the glass plate 2. The absorption film 4 is formed on the reflective film 3.

[0032]

The EUVL-use mask blank 1 illustrated in FIG. 4 is obtained by performing aforementioned S1 to S7. The EUVL-use mask blank 1 includes the glass plate 2, the reflective film 3, the absorption film 4, and the conductive film 5. The EUVL-use mask blank 1 need not necessarily include the conductive film 5. The mask blank 1 for EUVL may also include another type of film.

[0033]

For example, the EUVL-use mask blank 1 may further include a low-reflective film. The low-reflective film is formed on the absorption film 4. The low-reflective film is used for inspecting an opening pattern 41 of the absorption film 4 illustrated in FIG. 5, and has a lower reflection characteristic with respect to the inspection light than the absorption film 4. The low-reflective film is formed of, for example, TaON or TaO. A sputtering method is, for example, used as the method for forming the low-reflective film.

[0034]

The EUVL-use mask blank 1 may further include a protective film. The protective film is formed between the reflective film 3 and the absorption film 4. The protective film protects the reflective film 3 such that the reflective film 3 does not get etched when the

absorption film 4 is etched to form the opening pattern 41 in the absorption film 4. The protective film is formed of, for example, Ru, Si, or TiO₂. A sputtering method is, for example, used as a method for forming the protective film.

[0035]

As illustrated in FIG. 5, the EUVL-use photomask is obtained by forming an opening pattern 41 in the absorption film 4. Photolithography and etching methods are used to form the opening pattern 41. Therefore, the resist film used for forming the opening pattern 41 may be included in the mask blank 1 for EUVL.

[0036]

Next, the machining device used in S3 of FIG. 1 is described with reference to FIG. 6. The machining device 100 is what is known as a Gas Cluster Ion Beam (GCIB) machining device.

[0037]

The machining device 100 includes a vacuum vessel 101. The vacuum vessel 101 has a nozzle chamber 102, an ionization/acceleration chamber 103, and a processing chamber 104. The three chambers 102, 103, and 104 are connected together to form the passage of the gas cluster. The three chambers 102, 103, and 104 are evacuated by three vacuum pumps 105, 106, and 107 to maintain a desired degree of vacuum. The number of chambers and the number of vacuum pumps are not particularly limited.

[0038]

The machining device 100 includes a generation unit 110. The generation unit 110 generates gas clusters. The generation unit 110 includes, for example, a source tank 111, a pressure controller 113, supply piping 114, and a nozzle 116. The source tank 111 stores source gas (e.g., CF₄ gas). A pressure controller 113 controls the supply pressure of the source gas supplied from the source tank 111 to the nozzle 116 via the supply piping 114. A nozzle 116 is provided in the nozzle chamber 102 and jets the source gas into a vacuum to form a supersonic gas jet 118.

[0039]

The source gas is cooled by adiabatic expansion in the gas jet 118. As a result, part of the gas jet 118 condenses into gas clusters, each of which is an aggregate of several to several thousand atoms or molecules. Many gas clusters are contained near the center of the flow of the gas jet 118. Therefore, a skimmer 119 enables gas clusters to be efficiently delivered by passing gas clusters near only the center of the flow of the gas jet 118.

[0040]

The source gas is not limited to CF_4 gas, but may be SF_6 gas, Ar gas, O_2 gas, N_2 gas, NF_3 gas, N_2O gas, CHF_3 gas, C_2F_6 gas, C_3F_8 gas, C_4F_6 gas, SiF_4 gas, COF_2 gas, SeF_6 gas, TeF_6 gas, or WF_6 gas. More than one gas may be selected from these gases and a mixture may be used as the source gas. The source gas is preferably one that can form large-size gas clusters and can be etched at a high rate, and more specifically, is preferably one that contains fluorine.

[0041]

The machining device 100 includes an ionization unit 120. The ionization unit 120 ionizes at least part of the gas clusters in the gas jet 118. The ionization unit 120 includes one or more hot filaments 124 and includes a cylindrical electrode 126, for example. The hot filament 124 generates heat and emits thermal electrons by power (voltage V_F) from a power supply 125. The cylindrical electrode 126 accelerates the thermal electrons emitted from the hot filament 124, causing the accelerated thermal electrons to collide with the gas cluster. Collisions between electrons and gas clusters release electrons from part of the gas clusters, and these gas clusters become positively ionized. In some cases, two or more electrons are emitted and ionized multivalently. A voltage V_A from a power supply 127 is applied to between the cylindrical electrode 126 and the hot filament 124. This voltage V_A (electric field) accelerates the thermal electrons, causing the accelerated thermal electrons to collide with the gas cluster.

[0042]

The machining device 100 includes an acceleration unit 130. The acceleration unit 130 forms the GCIB 128 by accelerating the gas clusters ionized by the ionization unit 120. The acceleration unit 130 includes, for example, a first electrode 132 and a second electrode 134. The second electrode 134 is grounded, and a positive voltage V_s is applied from a power supply 135 to the first electrode 132. The first electrode 132 and the second electrode 134 form an electric field for accelerating the positively ionized gas cluster. The accelerated gas cluster is extracted from the opening of the second electrode 134 as the GCIB 128. A power supply 136 supplies an acceleration voltage V_{Acc} for biasing the ionization unit 120 to the first electrode 132 and the second electrode 134 so that the total GCIB acceleration potential is equal to V_{Acc} . V_{Acc} is, for example, 1 kV to 200 kV, and preferably 1 kV to 70 kV.

[0043]

The machining device 100 may include a neutralization

unit, which is not illustrated. The neutralization unit neutralizes the GCIB 128 formed by the acceleration unit 130 to form a neutral gas cluster. Since the glass plate 2 is irradiated with a neutral gas cluster, charging of the glass plate 2 can be prevented. Even if the glass plate 2 is irradiated with positively ionized gas clusters, the glass plate 2 can still be etched.

[0044]

The machining device 100 includes an irradiation unit 150. The irradiation unit 150 irradiates the glass plate 2 with a beam-shaped gas cluster 129 to locally etch the glass plate 2. The diameter of the beam of the gas cluster 129 is, for example, 1 mm to 15 mm. The irradiation unit 150 includes, for example, a stage 151, a stage moving mechanism 152, and an aperture 153. The stage 151 is installed in the processing chamber 104 and holds the glass plate 2. The stage moving mechanism 152 moves the stage 151 two-dimensionally in the Y-axis direction and in the Z-axis direction in order to move the point at which the glass plate 2 is irradiated with the gas cluster 129. By controlling the moving speed, the etching amount can be controlled, and the glass plate 2 can be flattened. The stage moving mechanism 152 can also move the stage 151 in the X-axis direction. The aperture 153 is provided at a location somewhere along the passage of the gas cluster 129 to enhance the uniformity of the intensity of the gas cluster 129. The gas cluster 129 passes through the opening of the aperture 153, and radiates the glass plate 2.

[0045]

Next, the irradiation unit 150 of the machining device 100 is described with reference to FIGS. 7 to 9. In this specification, the X-axis direction, the Y-axis direction, and the Z-axis direction are perpendicular to each other. The X-axis direction and the Y-axis direction are horizontal and the Z-axis direction is vertical. In the following description, the positive X-axis direction is forward and the negative X-axis direction is backward. The irradiation direction of the gas cluster 129 illustrated by an arrow in FIG. 7 is the positive X-axis direction.

[0046]

As illustrated in FIG. 7, the irradiation unit 150 radiates the beam-shaped gas cluster 129 forward and locally etches the first main surface 21 of the glass plate 2 with the radiated gas cluster 129. The first main surface 21 is disposed rearward and inclined obliquely upward. Since the first main surface 21 faces obliquely upward, the stage 151 can stably hold the glass plate 2 from below. If the orientation of the glass plate 2 is

reversed, local etching of the second main surface 22 of the glass plate 2 can of course also be performed.
[0047]

As illustrated in FIG. 9, the stage 151 is situated such that the stage 151 faces the second main surface 22 of the glass plate 2. The stage 151 is situated in front of the glass plate 2. The stage 151 may hold the glass plate 2, via, for example, a spacer 155. The spacer 155 forms a gap between the stage 151 and the glass plate 2. Compared with a case where the entirety of the second main surface 22 of the glass plate 2 is in contact with the stage 151, generation of a contact flaw on the second main surface 22 can be suppressed.
[0048]

The spacer 155 may have a tapered surface in a tapered shape. As long as the second chamfered surface 25 of the glass plate 2 is held by the tapered surface of the spacer 155, the second chamfered surface 25 is not brought into contact with the second main surface 22 at all, and thus an occurrence of a contact flaw on the second main surface 22 can be surely prevented. As illustrated in FIG. 8, part of the spacer 155 is disposed outside the glass plate 2 as seen in the irradiation direction of the gas cluster 129.
[0049]

In the present embodiment, part of the spacer 155 is disposed outside the glass plate 2 as seen in the irradiation direction of the gas cluster 129, but the entire spacer 155 can be disposed inside the glass plate 2. In this case, the spacer 155 does not come into contact with the second chamfered surface 25 of the glass plate 2, but comes into contact with a peripheral edge region excluding the quality assurance region of the second main surface 22.
[0050]

The stage 151 may hold the glass plate 2 via a clamp 156. The glass plate 2 can be stably held in a vacuum. The entire clamp 156 is situated outside the glass plate 2 as seen in the irradiation direction of the gas cluster 129. The clamp 156 butts against, for example, the end surface 23 of the glass plate 2. Multiple clamps 156 are provided along the peripheral edge of the glass plate 2 at intervals.
[0051]

Although the clamp 156 butts against the end surface 23 of the glass plate 2 in the present embodiment, the clamp 156 may also butt against the peripheral edge region 27 of the first main surface 21 of the glass plate 2. The clamp 156 may also butt against the first chamfered surface 24 of the glass plate 2. In these cases as well, part of

the clamp 156 is situated outside the glass plate 2 as seen in the irradiation direction of the gas cluster 129.
[0052]

Incidentally, the machining device 100 includes the stage 151, the spacer 155, the clamp 156, and the like as peripheral components of the glass plate 2. At least some of these peripheral components are arranged outside the glass plate 2 as seen in the irradiation direction of the gas cluster 129. Therefore, in the past, gas clusters 129 sometimes collided with these peripheral components as well, and the collision sometimes caused defects in the end surface 23 of the glass plate 2. In addition, in a case where the spacer 155 had formed a gap between the glass plate 2 and the stage 151, the second main surface 22 of the glass plate 2 also became defective at times.
[0053]

The defects are caused, for example, by flying debris. The flying debris are gas clusters 129 that have changed directions due to collisions with the peripheral components, or are particles that get projected from the peripheral components due to collisions between the gas clusters 129 and the peripheral components. The materials of the particles are the same as those of the peripheral components. Defects can also be caused by concave scratches or protruding deposits. The scar is the impact trace of the flying object, and the debris is the flying object itself. Damage includes impact-based damage from flying debris and deposits are the flying debris itself.
[0054]

Defects can also be caused by direct collision of the gas cluster 129. For example, in a case where the first main surface 21 of the glass plate 2 is inclined with respect to the irradiation direction (X-axis direction) of the gas cluster 129, the gas cluster 129 also directly collides with the end surface 23 of the glass plate 2. Hereinafter, the gas clusters 129 and the flying debris produced by the collision of gas cluster 129 with the peripheral components and are collectively referred to as fluid matter.
[0055]

As illustrated in FIG. 7, the irradiation unit 150 of this embodiment also has a blocking unit 160. The blocking unit 160 moves together with the stage 151 to block the fluid matter that is expected to form a defect on at least one of the second main surface 22 or the end surface 23 of the glass plate 2. Since the blocking unit 160 blocks the fluid, an occurrence of a defect can be suppressed. If defects of the second main surface 22 can be reduced, the time spent performing the subsequent final polishing of the

second main surface 22 can be shortened, and thus the second main surface 22 having a high degree of flatness yet few defects can be obtained. This is because when too much time is spent performing the final polishing, the number of defects can be reduced but at the expense of adversely affecting the degree of flatness.

[0056]

The blocking unit 160 includes, for example, a shield plate 161. The shield plate 161 is situated such that the shield plate 161 faces the first main surface 21 of the glass plate 2 and is behind the glass plate 2. The shield plate 161 need not come into contact with the glass plate 2 and may form a gap with the glass plate 2. The shield plate 161 is formed in a frame shape and is situated such that the shield plate 161 overlaps with an entirety of the peripheral edge of the glass plate 2 as illustrated by the dashed line in FIG. 8 as seen in the irradiation direction of the gas cluster 129. The shield plate 161 can block the gas clusters 129 which would otherwise directly collide with the end surface 23 of the glass plate 2 before any collision, and thus reduce defects of the end surface 23. In addition, since the shield plate 161 blocks the gas clusters 129, which are expected to collide with the peripheral components, before any collision, defects on the second main surface 22 and in the end surface 23 can be reduced. As seen in the irradiation direction of the gas cluster 129, the spacer 155 and the clamp 156 are covered with the shield plate 161. In addition, as seen in the irradiation direction of the gas cluster 129, the part of the stage 151 that is outside the glass plate 2 and is within the first predetermined distance from the peripheral edge of the glass plate 2 is covered and concealed by the shield plate 161. The first predetermined distance is 125% of the distance from the first main surface 21 (rear surface) of the glass plate 2 to the rear surface of the stage 151.

[0057]

The shield plate 161 is situated outside the quality assurance region 26 so as not to overlap with the quality assurance region 26 of the first main surface 21 of the glass plate 2 as seen in the irradiation direction of the gas cluster 129. This is done to flatten the quality assurance region 26. The size of an opening 161a of the shield plate 161 is greater than or equal to the size of the quality assurance region 26 as seen in the irradiation direction of the gas cluster 129.

[0058]

The shield plate 161 of the present embodiment is formed in a frame shape as seen in the irradiation

direction of the gas cluster 129 and is situated so as to overlap the entire peripheral edge of the glass plate 2, but the technique of the present disclosure is not limited to this. For example, multiple shield plates 161 may be arranged along the peripheral edge of the glass plate 2 at intervals as seen in the irradiation direction of the gas cluster 129. It is sufficient as long as an occurrence of defects can be suppressed in at least part of the peripheral edge of the glass plate 2.

[0059]

The material of the shield plate 161 may be metal, resin, or ceramic. However, when the gas cluster 129 collides with the shield plate 161, particles of the shield plate 161 may scatter to the glass plate 2. Therefore, it is preferable that the material of the shield plate 161 is one that can be removed when the glass plate 2 is cleaned.

[0060]

Cleaning of the glass plate 2 includes, for example, RCA cleaning. RCA cleaning includes, for example, SC-1 cleaning, diluted hydrofluoric acid cleaning, and SC-2 cleaning in this order. In the SC-1 cleaning, a mixed aqueous solution of ammonium hydroxide (NH_4OH) and hydrogen peroxide (H_2O_2) is used as the cleaning fluid. In diluted hydrofluoric acid cleaning, diluted hydrofluoric acid is used as the cleaning fluid. In the SC-2 cleaning, a mixed aqueous solution of hydrochloric acid (HCl) and hydrogen peroxide is used as the cleaning fluid. RCA cleaning may further include SPM cleaning. In SPM cleaning, a mixed aqueous solution of sulfuric acid (H_2SO_4) and hydrogen peroxide is used as a cleaning solution.

[0061]

The cleaning of the glass plate may include scrubbing. During the scrubbing, the glass plate is scrubbed and cleaned with a brush or sponge. The scrubbing may be used alone or as part of RCA cleaning.

[0062]

Aluminum, copper, iron, nickel, zinc, titanium, stainless steel, or brass is used as the material of the shield plate 161. These metals can be removed by performing RCA cleaning.

[0063]

As the material that is the resin of the shield plate 161, vinyl acetate resin, ethylene-vinyl acetate copolymer resin, isobutene-maleic anhydride copolymer resin, acrylic copolymer resin, styrene-butadiene rubber copolymer, vinyl chloride resin, chloroprene rubber, nitrile rubber, epoxy resin, modified epoxy resin, silicone resin, modified silicone resin, urethane resin, EVA resin, ABS resin, polypropylene, high-density polyethylene, low-density

polyethylene, polystyrene, polyester, polyamide, polyvinyl chloride, polycarbonate, PET (Poly Ethylene Terephthalate), POM (Poly Oxy Methylene), PBT (Poly Butylene Terephthalate), polyvinylidene chloride, PVA (Poly Vinyl Alcohol), or fluoro-resin is used. As the resin that is the material of the shield plate 161, PPSU (Poly Phenyl Sulfone), PSU (Poly Sulfone), PAR (Poly Arylate), PEI (Poly Ether Imide), PEEK (Polyether Ether Ketone), PPS (Poly Phenylene Sulfide), PES (Poly Ether Sulfone), PAI (Poly Amide Imide), LCP (Liquid Crystal Polymer), PTFE (Poly Tetra Fluoro Ethylene), PCTFE (Poly Chloro TriFluoro Ethylene), or PVDF (Poly Vinylidene DiFluoride). These resins can be removed by RCA cleaning or scrubbing.

[0064]

As the ceramic that is the material of the shield plate 161, alumina, zirconia, aluminum nitride, silicon carbide, silicon nitride, forsterite, steatite, cordierite, sialon, machinable ceramic, barium titanate, lead zirconate titanate, ferrite, or mullite is used.

[0065]

If the orientation of the glass plate 2 is reversed as described above, local etching of the second main surface 22 of the glass plate 2 can of course also be performed. In this case, the blocking unit 160 moves together with the stage 151 to block the fluid that is expected to form a defect on at least one of the first main surface 21 and end surface 23 of the glass plate 2. Since the blocking unit 160 blocks the fluid matter, an occurrence of a defect can be suppressed. If defects of the first main surface 21 can be reduced, the time spent performing the subsequent final polishing of the first main surface 21 can be shortened, and thus the first main surface 21 having a high degree of flatness yet few defects can be obtained. This is because when too much time is spent performing the final polishing, the number of defects can be reduced but at the expense of adversely affecting the degree of flatness.

[0066]

Next, with reference to FIG. 10, the stage 151 according to the modified example is described. The stage 151 is situated such that the stage 151 faces the second main surface 22 of the glass plate 2 as described above. The stage 151 is situated in front of the glass plate 2.

[0067]

The stage 151 includes an opening 151a through which the gas cluster 129 passes. The opening 151a is situated such that the opening 151a overlaps with the entire peripheral edge of the glass plate 2 as seen in the irradiation direction of the gas cluster 129 as illustrated in FIG. 10. Collision between the gas cluster 129 and the

stage 151 can be suppressed in the vicinity of the peripheral edge of the glass plate 2, and an occurrence of defects due to the collision can be suppressed.

[0068]

Multiple openings 151a of the stage 151 may be formed along the peripheral edge of the glass plate 2 at intervals. The opening 151a may be provided between a spacer 155 and a clamp 156 that are adjacent to each other or may be provided between two clamps 156 that are adjacent to each other.

[0069]

Incidentally, at least part of the spacer 155 and the clamp 156 are arranged outside the glass plate 2 as seen in the irradiation direction of the gas cluster 129.

Therefore, the gas cluster 129 may also collide with the spacer 155 and the clamp 156.

[0070]

Therefore, the stage 151 of this modified example may be used in combination with the shield plate 161 of the aforementioned embodiment. As seen in the irradiation direction of the gas cluster 129, the spacer 155 and the clamp 156 may be covered and concealed by the shield plate 161.

[0071]

In such a case, multiple shield plates 161 may be arranged along the peripheral edge of the glass plate 2 at intervals as viewed in the irradiation direction of the gas cluster 129. The opening 151a of the stage 151 is provided between the shield plates 161 that are adjacent to each other as viewed in the irradiation direction of the gas cluster 129.

[0072]

Next, with reference to FIG. 11, the blocking unit 160 in the modified example is described. The blocking unit 160 may include a mask 162 that covers the second main surface 22 of the glass plate 2 and may include a mask 163 that covers the end surfaces 23 of the glass plate 2. It is sufficient as long as the blocking unit 160 contains at least one of the two masks 162 and 163.

[0073]

The mask 162 covers the second main surface 22 of the glass plate 2 and blocks the fluid matter, which is expected to form a defect on the second main surface 22, before otherwise colliding with the second main surface 22. Therefore, the occurrence of defects on the second main surface 22 can be suppressed. The mask 162 covers the entirety of the second main surface 22 in this modified example, but it is sufficient as long as the mask 162 at least covers a portion that is within the second

predetermined distance from the end surface 23. The second predetermined distance is 200% of the gap between the stage 151 and the glass plate 2 formed by the spacer 155. In other words, the predetermined distance is 200% of the distance from the second main surface 22 (front surface) of the glass plate 2 to the rear surface of the stage 151.
[0074]

The mask 163 covers the end surface 23 of the glass plate 2 and blocks fluid matter, which is expected to form a defect on the end surface 23, before otherwise colliding with the end surface 23. Therefore, an occurrence of defects on the end surface 23 can be suppressed. The mask 163 covers the end surface 23 over the entire peripheral edge of the glass plate 2 in this this modified example, but it is sufficient as long as the mask 163 covers the end surface 23 along, at least, only a portion of the peripheral edge of the glass plate 2.
[0075]

Preferably, the materials of the masks 162 and 163 are removable as the glass plate 2 is cleaned. Cleaning of the glass plate 2 is, for example, RCA cleaning. Scrubbing may be used. Scrubbing may be used alone or as part of RCA cleaning. The masks 162 and 163 may be single-layered or multi-layered.
[0076]

Preferably, the masks 162 and the 163 contain a resin layer as a layer that is brought into contact with the glass plate 2. The resin layer may be a single layer or may be multiple layers. The resin layer contains no filler and no powder at least at the contact surface with the glass plate 2. This is because fillers and powders can cause dust or scratches. Preferably, the resin layer does not contain any filler or powder not only on the contact surface with the glass plate 2 but also inside.
[0077]

The resin layer can be easily removed by scrubbing. During the scrubbing, the resin layer is scrubbed and cleaned with a brush or sponge. During the scrubbing, an alkaline solution containing a surfactant may be used as the cleaning fluid. Removal efficiency can be improved by the action of alkali. The scrubbing may be combined with ultrasonic cleaning.
[0078]

Note that the masks 162 and 163 of this modified example may be used in combination with the shield plate 161 of the aforementioned embodiment or in combination with the stage 151 of the aforementioned modified example.
[0079]

Next, the blocking unit 160 according to another

modified example is described with reference to FIG. 12. The blocking unit 160 includes the mask 163 that covers the end surfaces 23 of the glass plate 2. Since this mask 163 also seals the gap between the glass plate 2 and the stage 151, an occurrence of defects on the second main surface 22 can also be suppressed. According to this modified example, since the mask 162 illustrated in FIG. 12 is unnecessary, the removal of the mask 162 is also unnecessary, and thus the glass plate 2 can be easily cleaned.

[0080]

The mask 163 of this modified example may be used in combination with the shield plate 161 of the above embodiment or in combination with the stage 151 of the aforementioned modified example.

(Examples)

[0081]

The experimental data is described below. Examples 1 and 2 below are examples and Example 3 is a comparative example.

[0082]

In Example 1, the first main surface 21 of the glass plate 2 was machined with the beam-shaped gas cluster 129 by the machining device 100 illustrated in FIG. 6. The machining conditions were as follows:

Material of the glass plate 2: Quartz glass containing TiO_2

Source gas: CF_4 gas

Acceleration voltage V_{ACC} : 60 kV

Material of the stage 151: Aluminum

Shape of the stage 151: Shape in FIG. 10

Material of the shield plate 161: Aluminum

Shape of the shield plate 161: Shape in FIG. 8

With or without the masks 162 and 163: Without.

[0083]

In Example 1, the gas cluster 129 was restricted from colliding with the stage 151, which is a peripheral component of the glass plate 2, by the shield plate 161. As a result, no deposits of the aluminum particles (particles flying out from the stage 151 due to the collisions of the gas clusters 129) were visually confirmed were confirmed on the end surface 23 and the second main surface 22 of the glass plate 2.

[0084]

In Example 2, the first main surface 21 of the glass plate 2 was machined with a beam-shaped gas cluster 129 under the same machining conditions as in Example 1, except that the shield plate 161 was not used. In Example 2, in the region where the opening 151a of the stage 151 overlaps

with the peripheral edge of the glass plate 2 as seen in the irradiation direction of the gas cluster 129, no deposits of aluminum particles were visually observed on the second main surface 22 and end surface 23 of the glass plate 2. However, as seen in the irradiation direction of the gas cluster 129, in the region where the opening 151a of the stage 151 does not overlap with the peripheral edge of the glass plate 2, a small amount of deposits of aluminum particles were visually confirmed on the second main surface 22 and on the end surface 23 of the glass plate 2.

[0085]

In Example 3, the first main surface 21 of the glass plate 2 was machined with a beam-shaped gas cluster 129 under the same machining conditions as in Example 1, except that the shield plate 161 was not used and the stage 151 without the opening 151a was used. In Example 3, deposits of aluminum particles were visually confirmed on the second main surface 22 and the end surface 23 of the glass plate 2 over the entire peripheral edge of the glass plate 2.

[0086]

From the results of Examples 1 to 3, it can be seen that deposition of aluminum particles (particles flying out from the stage 151 due to the collision of the gas clusters 129) can be suppressed by using the shield plate 161 or by forming the opening 151a in the stage 151.

[0087]

As described above, the machining method and the machining device method for the glass plate, and the manufacturing method for the EUVL-use mask blank according to the present disclosure have been described. However, the present disclosure is not limited to the above-described embodiments. Various variations, modifications, substitutions, additions, deletions, and combinations are possible within the scope recited in the claims. They are also of course within the technical scope of the present disclosure.

[0088]

For example, the application of the glass plate machined by the machining method and the machining device of the present disclosure is not limited to EUVL. It is sufficient as long as the application of the glass plate is an application where a high degree of flatness is required, and may be, for example, a medical apparatus. The glass composition of the glass plate may be one that is suitable for the application of the glass plate.

[0089]

This application claims priority based on Japanese Patent Application No. 2020-084728 filed with the Japan

Patent Office on May 13, 2020, and the entire content of Japanese Patent Application No. 2020-084728 is incorporated herein by reference.

REFERENCE NUMERALS LIST

[0090]

- 1 EUVL-use mask blank
- 2 Glass plate
- 21 First main surface
- 22 Second main surface
- 23 End surface
- 3 Reflective film
- 4 Absorption film
- 100 Machining device
- 129 Gas cluster
- 150 Irradiation unit
- 151 Stage
- 151a Opening
- 152 Stage moving mechanism
- 155 Spacer
- 156 Clamp
- 160 Blocking unit
- 161 Shield plate
- 162, 163 Mask

CLAIMS

[Claim 1]

A machining method comprising:
irradiating a first main surface of a glass plate with a beam-shaped gas cluster;
moving the glass plate such that a point at which the first main surface of the glass plate is irradiated with the gas cluster is moved; and
blocking fluid matter that is expected to form a defect on at least one of a second main surface of the glass plate and an end surface of the glass plate by using a blocking unit that moves together with the glass plate, the second main surface being opposite to the first main surface.

[Claim 2]

The machining method according to claim 1, wherein
the blocking unit includes a shield plate that is situated such that the shield plate faces the first main surface of the glass plate, and
the shield plate is situated such that the shield plate overlaps with a peripheral edge of the glass plate as seen in an irradiation direction of the gas cluster.

[Claim 3]

The machining method according to claim 2, wherein the shield plate is formed in a frame shape and is situated such that the shield plate overlaps with an entirety of the peripheral edge of the glass plate as seen in the irradiation direction of the gas cluster.

[Claim 4]

The machining method according to any one of claims 1 to 3, wherein the blocking unit includes at least one of a mask that covers the second main surface of the glass plate and a mask that covers the end surface of the glass plate.

[Claim 5]

The machining method according to any one of claims 1 to 4, wherein

a stage that holds the glass plate is situated such that the stage faces the second main surface of the glass plate and is configured to hold the glass plate via a spacer, and

the spacer forms a gap between the glass plate and the stage.

[Claim 6]

The machining method according to claim 5, wherein part of the spacer is situated outside the glass plate as seen in the irradiation direction of the gas cluster.

[Claim 7]

The machining method according to any one of claims 1 to 6, wherein

a stage that holds the glass plate is situated such that the stage faces the second main surface of the glass plate and is configured to hold the glass plate via a clamp, and

at least part of the clamp is situated outside the glass plate as seen in an irradiation direction of the gas cluster.

[Claim 8]

The machining method according to any one of claims 1 to 7, wherein

a stage that holds the glass plate is situated such that the stage faces the second main surface of the glass plate, and has an opening through which the gas cluster is to be passed, and

the opening of the stage is provided such that the opening overlaps with a peripheral edge of the glass

plate as seen in an irradiation direction of the gas cluster.

[Claim 9]

A machining method comprising:
irradiating a first main surface of a glass plate with a beam-shaped gas cluster; and
moving the glass plate such that a point at which the first main surface of the glass plate of the gas cluster is irradiated with the gas cluster is moved,
wherein a stage that holds the glass plate is situated such that the stage faces a second main surface of the glass plate, and has an opening through which the gas cluster is to be passed, the second main surface being opposite to the first main surface, and
wherein the opening of the stage is provided such that the opening overlaps with a peripheral edge of the glass plate as seen in an irradiation direction of the gas cluster.

[Claim 10]

A manufacturing method for an EUVL-use mask blank, the manufacturing method comprising:
flattening a first main surface of a glass plate by using the machining method of any one of claims 1 to 9;
forming a reflective film that reflects EUV light, the reflective film being formed on the first main surface of the glass plate; and
forming an absorption film that absorbs the EUV light, the absorption film being formed on or above the reflective film.

[Claim 11]

A machining device comprising:
an irradiation unit that irradiates a first main surface of a glass plate with a beam-shaped gas cluster;
a stage that holds the glass plate;
a stage moving mechanism that moves the stage such that a point at which the first main surface of the glass plate is irradiated with the gas cluster is moved;

and

a blocking unit that blocks fluid matter that is expected to form a defect on or in at least one of a second main surface of the glass plate and an end surface of the glass plate by moving together with the stage, the second main surface being opposite to the first main surface.

[Claim 12]

A machining device comprising:

an irradiation unit that irradiates a first main surface of a glass plate with a beam-shaped gas cluster, wherein the irradiation unit includes

a stage that holds the glass plate, and
a stage moving mechanism that moves the stage such that a point at which the first main surface of the glass plate is irradiated with the gas cluster is moved, and

wherein the stage is situated such that the stage faces a second main surface of the glass plate, and has an opening through which the gas cluster is to be passed, the second main surface being opposite to the first main surface, and

wherein the opening of the stage is provided such that the opening overlaps with a peripheral edge of the glass plate as seen in an irradiation direction of the gas cluster.