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(54) **IMMERSION LITHOGRAPHY APPARATUS AND TANK THEREOF**

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See application file for complete search history.

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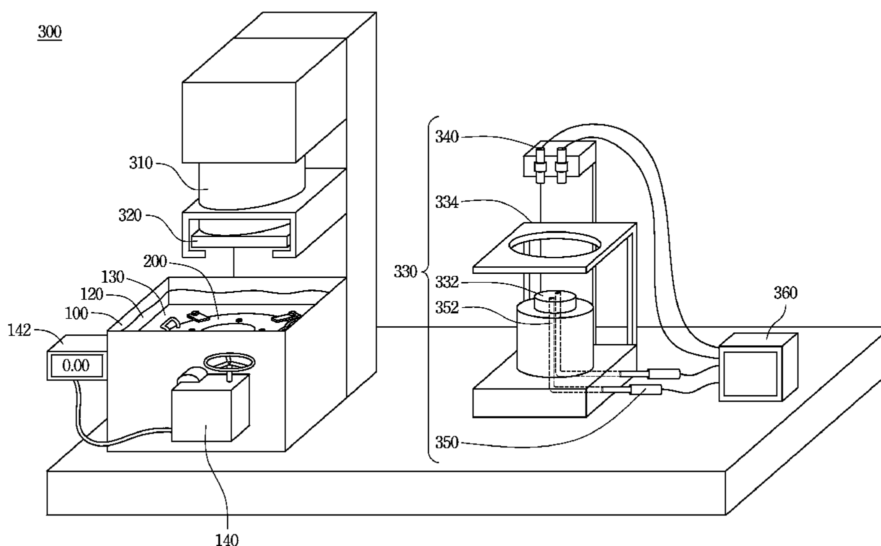
(57) **ABSTRACT**

An immersion lithography apparatus including a container, at least a liquid, a platform, a fixture, a roller, a light source, and a filter is provided. The container includes a bottom plate, a plurality of side plates, and a bearing hole penetrated through one of the side plates. The liquid is filled in the container. The platform is immersed in the liquid. The platform includes a pair of axles. The axles are parallel to the bottom plate. One of the axles passes through the bearing hole. The fixture is mounted on the platform for clamping a mask and a wafer. The roller is connected to the axle, passes through the bearing hole, and is operated to rotate the connected axle. The light source generates ultraviolet light to incident on the mask and the wafer. The filter is located between the light source and the fixture.

7 Claims, 4 Drawing Sheets



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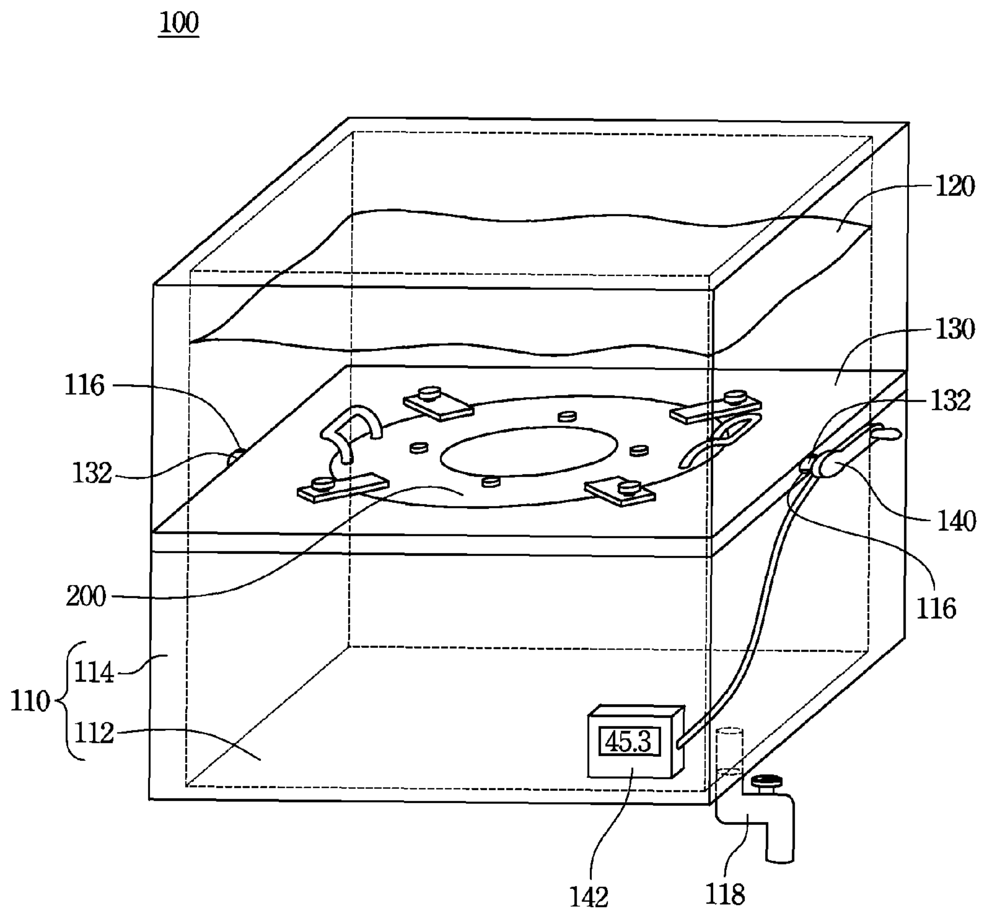

Fig. 1A

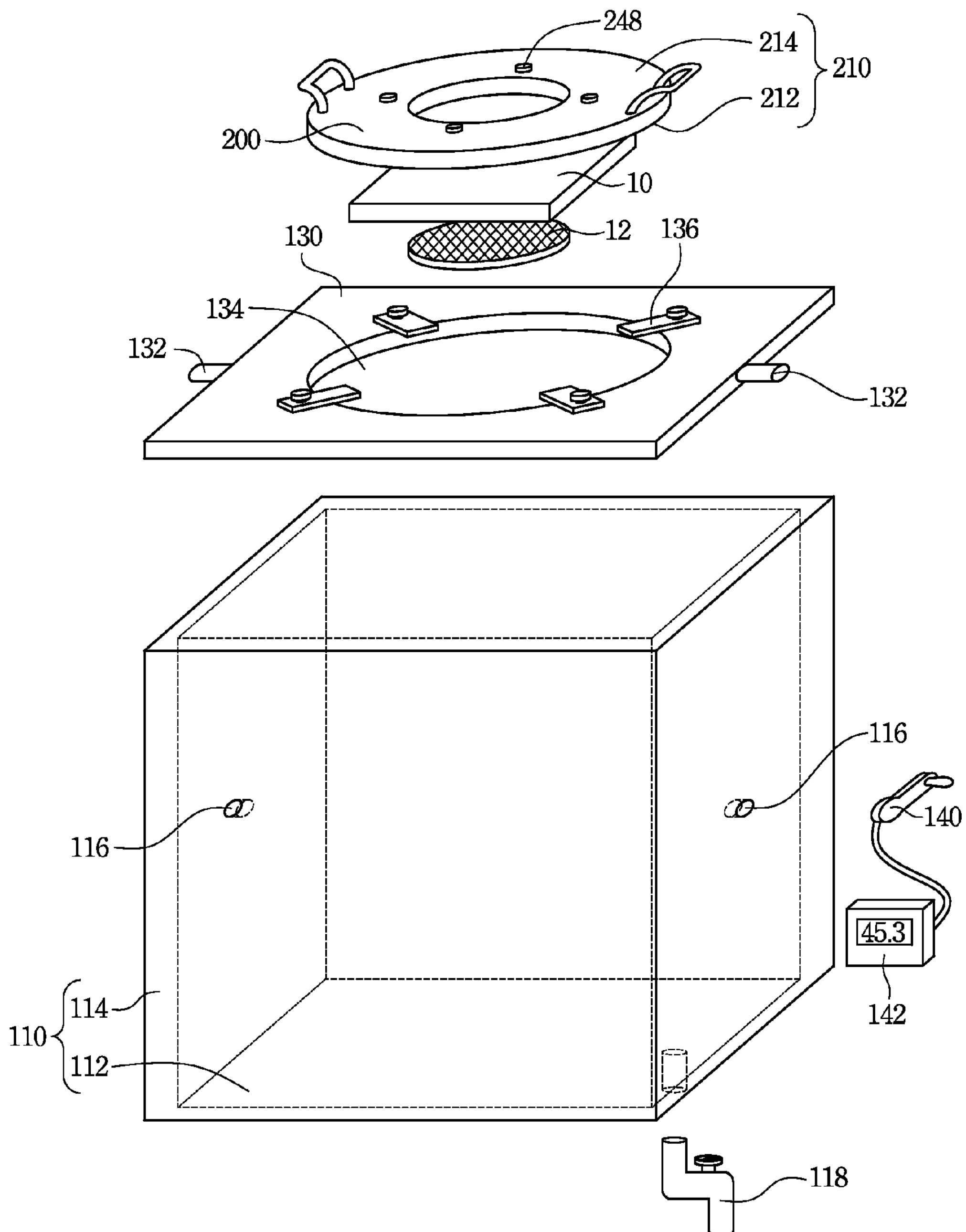

Fig. 1B

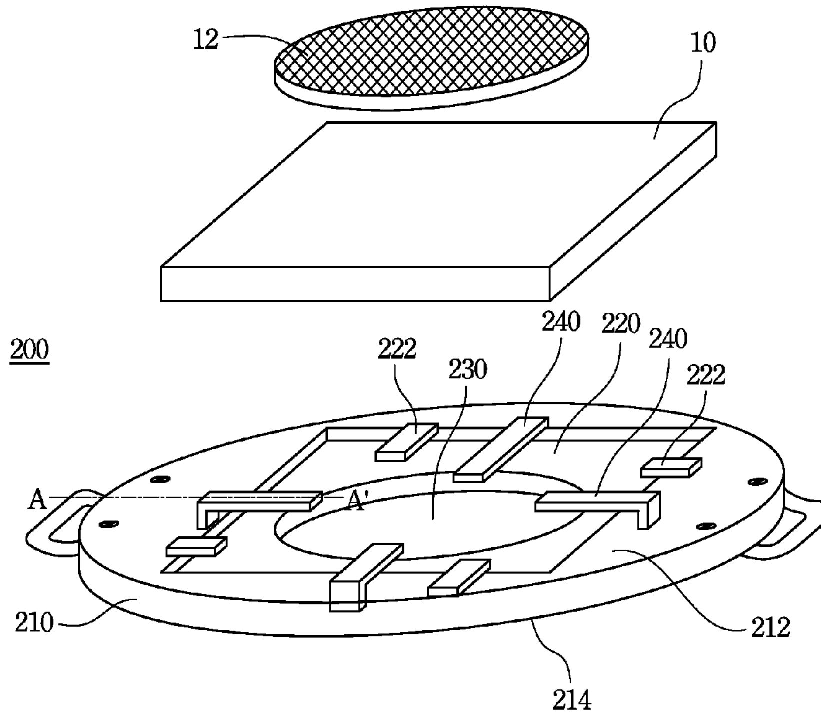

Fig. 2A

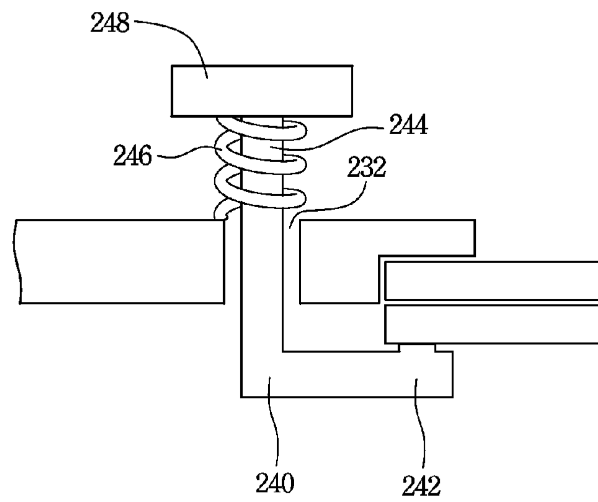

Fig. 2B

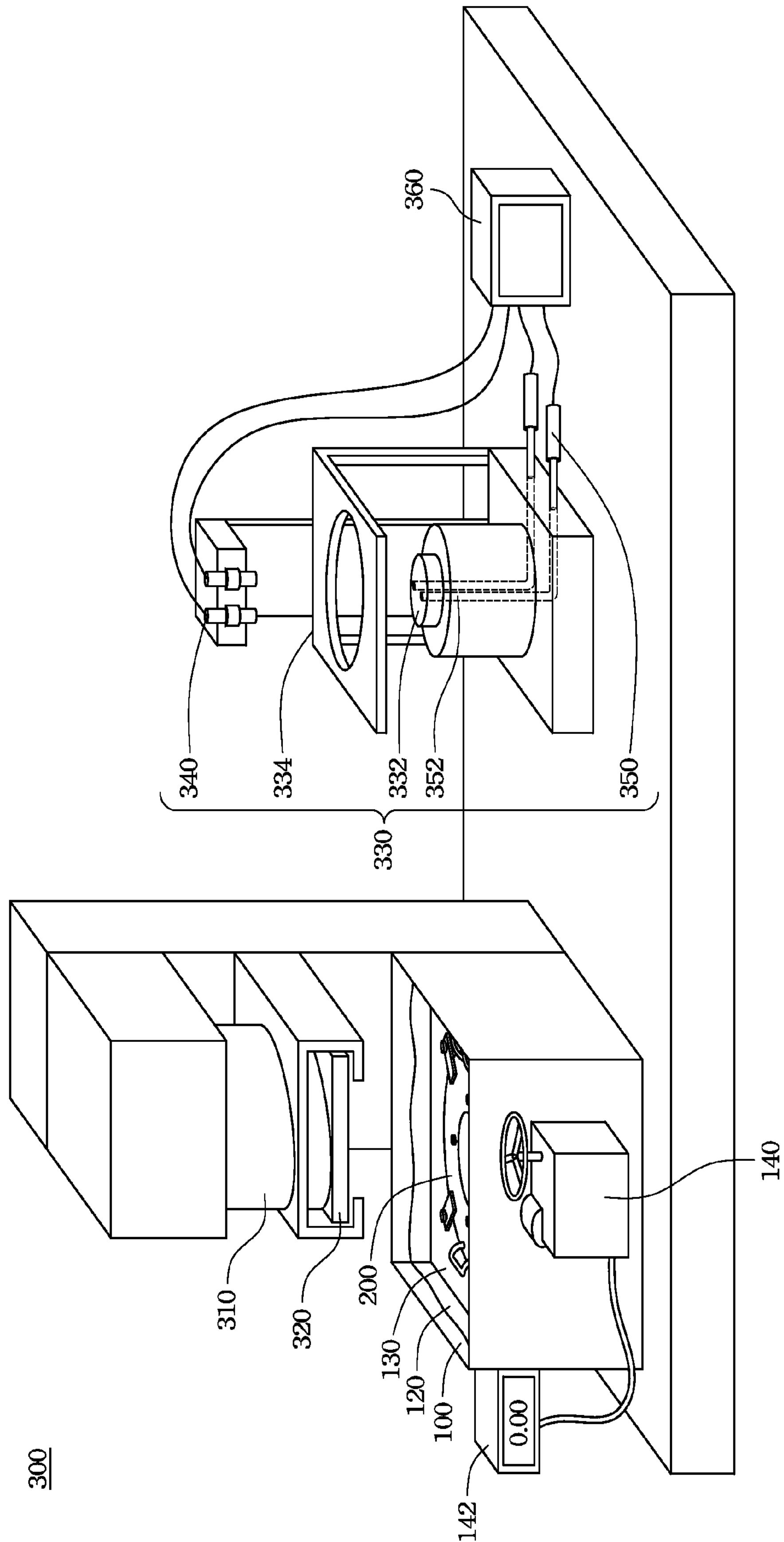

Fig. 3

IMMERSION LITHOGRAPHY APPARATUS AND TANK THEREOF

RELATED APPLICATIONS

This is a divisional application of patent application Ser. No. 12/400,119 filed on Mar. 9, 2009, now U.S. Pat. No. 8,189,175, which was based on, and claims priority from, Taiwan Patent Application No. 97138226, filed on Oct. 3, 2008, the disclosures of which are hereby incorporated by reference herein in their entireties.

BACKGROUND

1. Field of Invention

The present invention relates to an apparatus for semiconductor fabrication. More particularly, the present invention relates to an apparatus for immersion lithography.

2. Description of Related Art

Lithography process is one of the most important processes of semiconductor fabrication. Lithography process uses light to transfer geometric patterns from a mask to a light-sensitive chemical such as photoresist on a substrate of a wafer. A series of chemical treatments then engrave the exposure pattern on the wafer underneath the photoresist layer to form micro-structures or transistors.

Conventionally, a photolithography process is carried out under normal incidence, which means that the principal plane of the photoresist layer to be photo-structured is about perpendicular to the main direction of a light beam. However, it is hard to produce three-dimensional micro-structures with inclined flanks by using the conventional photolithography apparatus.

Therefore, a new apparatus for performing lithography with normal and inclined incidence is needed. The apparatus may control the inclined angle precisely to ensure the inclined flanks of the three-dimensional micro-structures.

SUMMARY

A tank for an immersion lithography apparatus is provided. The tank has a container with a bottom plate and side plates connected to one another, wherein the side plates surround and connect all edges of the bottom plate. At least a bearing hole penetrates through one of the side plates. The container is filled in at least a liquid, wherein a refractive index of the liquid is ranging from about 1.4 to about 1.8.

A platform is located in the container and immersed in the liquid. The platform has a pair of axles fastened separately on opposite sides thereof. The axles are parallel to the bottom plate, and one of the axles passes through the bearing hole. A roller disposed outside the container connects to the axle passing through the bearing hole to rotate the connected axle, and furthermore, to incline the platform accordingly.

During lithography process, a mask and a wafer with a layer of photoresist may be mounted on the platform, which may be inclined by rotating the roller. Therefore, three-dimensional micro-structures with inclined flanks may be formed on the photoresist layer on the wafer after lithographing. Additionally, refraction occurs when light travels from a medium to another, which usually causes a change of direction of the light or a change of incident angle. In an embodiment of this invention, the refractive index of the liquid is similar to or about equal to a refractive index of the photoresist so that the change of the incident angle may be smaller.

The invention provides an immersion lithography apparatus. The immersion lithography apparatus may perform normal and inclined lithography. The immersion lithography apparatus has a light source, a filter, a fixture, a platform, and a container. The fixture clamps at least a mask and a wafer. The light source may generate ultraviolet light incident on the mask and the wafer. The filter is located in a path of the ultraviolet light interposed between the light source and the fixture.

The container has a bottom plate and side plates connected to one another, wherein the side plates surround and connect all edges of the bottom plate. At least a bearing hole penetrated through one of the side plates. A platform is located in the container. The platform has a pair of axles fastened on opposite sides thereof. One of the axles passes through a bearing hole.

A roller disposed outside the container connects to the axle passing through a bearing hole to rotate the axle, and furthermore, to incline the platform accordingly. After lithographing, three-dimensional micro-structures with inclined flanks may be formed on the photoresist layer of the wafer.

The container is filled in at least a liquid, wherein the platform, the fixture, the mask and the wafer may be immersed in the liquid. A refractive index of the liquid is ranging from about 1.4 to about 1.8, which is similar to a refractive index of the photoresist layer on the wafer. Therefore, when light travels from the liquid to the photoresist layer, the change of the incident angle may be smaller.

It is to be understood that both the foregoing general description and the following detailed description are by examples, and are intended to provide further explanation of the invention as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention can be more fully understood by reading the following detailed description of the embodiments, with reference made to the accompanying drawings as follows:

FIG. **1**A is a three-dimensional view of a tank according to one embodiment of this invention;

FIG. **1**B is an exploded view of the tank shown in FIG. **1**A;

FIG. **2**A is a bottom view of the fixture shown in FIG. **1**A;

FIG. **2**B is a cross sectional view of the fixture shown in FIG. **2**A;

FIG. **3** is a three-dimensional view of an immersion lithography apparatus according to another embodiment of this invention.

DETAILED DESCRIPTION

Reference will now be made in detail to the present embodiments of the invention, examples of which are illustrated in the accompanying drawings. Wherever possible, the same reference numbers are used in the drawings and the description to refer to the same or like parts.

Please refer to FIG. **1**A and FIG. **1**B at the same time. FIG. **1**A and FIG. **1**B are a three-dimensional view and an exploded view of a tank **100** according to one embodiment of this invention. The tank **100** has a container **110**, a platform **130**, and a roller **140**.

The container **110** has a bottom plate **112** and side plates **114**. The side plates **114** connect to one another and the bottom plate **112**. In particular, the side plates **114** surround and connect all edges of the bottom plate **112**. In the embodiment of this invention, the container **110** is in a form of a pot with an opening for containing at least a liquid **120** like oil, glycerin, etc.

In the embodiment of this invention, the container **110** has a valve **118** disposed on the bottom plate **112** or one of the side

plates **114** to regulate flow of the liquid **120**. When the valve **118** is turned on, the liquid **120** may flow out of the container **110**.

At least a bearing hole **116** penetrates through one of the side plates **114**. In the embodiment of this invention, two bearing holes **116** are disposed separately on a pair of opposite side plates **114** of the container **110**. The bearing holes **116** are aligned.

A platform **130** is located in the container **110**. The platform **130** has an axle **132** fastened on a side thereof. The axle **132** is parallel to the bottom plate **112**. In the embodiment of this invention, the platform **130** has two axles **132** separately fastened on a pair of opposite sides thereof, wherein a linking line between the axles **132** may pass through a center of the platform.

When the platform **130** is placed in the container **110**, the axle **132** may pass through the bearing hole **116**. In the embodiment of this invention, the axles **132** pass through the bearing holes **116** on two opposite side plates **114**, and let the platform **130** suspend above the bottom plate **112** inside the container **110**.

The platform **130** may be used to mount a mask **10** and a wafer **12**. In the embodiment of this invention, the mask **10** and the wafer **12** are clamped on a fixture **200**, wherein the fixture **200** may be mounted on the platform **130**.

The platform **130** comprises a mount **134** disposed in the middle thereof. The mount **134** penetrates through the platform **130**. The shape and the size of the mount **134** are about equal to the shape and the size of the fixture **200** so that the fixture **200** may be mounted by the mount **134**. An inner surface of the mount **134** may engage the fixture **200**.

The platform **130** further comprises a plurality of fixture clamps **136** disposed surrounding the mount **134** to clamp the fixture **200**. In particular, each fixture clamp **136** is fastened on the platform **130** near an edge of the mount **134**, wherein part of each fixture clamp **136** protrudes over the edge of the mount **134**. When the fixture **200** is mounted by the mount **134**, part of each fixture clamp **136** protruded over the edge of the mount **134** may contact the fixture **200**.

A roller **140** is disposed near the bearing hole **116** outside the container **110**. The roller **140** connects to the axle **132** passing through the bearing hole **116** to rotate the axle **132**, and furthermore, to incline the platform **130** accordingly. In the embodiment of this invention, the roller **140** connects to part of the axle **132** protruded out of the bearing hole **116**. When using the roller **140** to rotate the axle **132**, the platform **130** may be rotated with the axle **132**. Therefore, the platform **130** may be inclined accordingly. The structure of the roller **140** may be many. The roller **140** is described here as an example, and not to limit the scope of the invention.

In the embodiment of this invention, the immersion lithography apparatus **100** further comprises a protractor **142** connecting the roller **140** to measure the rotating angle of the roller **140**. Since the axle **132** and the platform **130** may rotate with the roller **140**, the rotating angle of the roller **140** may be referred to the rotating angle of the axle **132** and the inclined angle of the platform **130**. The structure and the operation method for the protractor **142** are many. In an embodiment of this invention, the protractor **142** may measure the rotating angle of the axle **132**. In another embodiment of this invention, the axle **132** may have threads, and the protractor **142** may detect the threads to calculate the rotating angle of the axle **132** and the inclined angle of the platform **130**. Additionally, the roller **140** may have threads engaged with the threads of the axle **132**. The protractor **142** may detect the threads of the roller **140** to calculate the inclined angle of the platform **130**.

Please refer to FIG. **1**A to FIG. **2**B at the same time. FIG. **2**A is a bottom view of the fixture **200**. FIG. **2**B is a cross sectional view of the fixture **200** according to A-A' line shown in FIG. **2**A. The fixture **200** may clamp at least a mask **10** and a wafer **12**. The fixture **200** may be mounted on the platform **130** immersed in the liquid **120** when performing the immersion lithography process.

The fixture **200** comprises a base **210** with at least a side surface, a first surface **212** and a second surface **214**, wherein the first surface **212** and the second surface **214** are a pair of opposite surfaces of the base **210**. The side surface may connect all edges of the first surface **212** and the second surface **214**. The shape of the base **210** is not limited such as a circle, a square, a rectangle, or an ellipse. The shape of the base **210** may be similar to the shape of the mount **134** on the platform **130**. In the embodiment of this invention, the shape of the base **210** is a circle almost the same as the shape of the mount **134**.

A cavity **220** is disposed in the middle of the first surface **212** of the base **210** for containing the mask **10**, wherein an opening of the cavity **220** is located in the first surface **212**. The shape and the size of the cavity **220** are similar to the mask **10**. The depth of the cavity **220** may about equal to or larger than the thickness of the mask **10**.

To clamp the mask **10** in the cavity **220**, the fixture **200** has a plurality of mask clamps **222** disposed surrounding the cavity **220**. Each mask clamp **222** has two ends, wherein one of the ends is fastened on the base **210** and the other end protruded over an edge of the cavity **220** for contacting the mask **10**. In the embodiment of this invention, the mask clamps **222** are fastened on the base **210** by screws or latches.

The fixture **200** further has an exposing hole **230** for light generated from the light source **310** passing through to incident on the mask **10** and the wafer **12**. The exposing hole **230** may be disposed in the cavity **220** and penetrated through the base **210**. The area of the exposing hole **230** may be smaller than the area of the cavity **220**. Therefore, the mask **10** may be sandwiched between the bottom of the cavity **220** and the mask clamp **222**.

The fixture **200** further comprises structures to clamp the wafer **12** aligned to the mask **10**. In particular, the fixture **200** comprises at least a through hole **232**, at least a wafer clamp **240**, and a spring **246**.

The through hole **232** may be disposed on the base **210** near the cavity **220**. In the embodiment of this invention, a plurality of through holes **232** surrounds the cavity **220**. The through holes **232** penetrate through the base **210** out of the cavity **220**, wherein two openings of the through holes **232** are disposed on the first surface **212** and the second surface **214**.

The wafer clamp **240** has a first rod **242** and a second rod **244**. The first rod **242** extends parallel the first surface **212**. The second rod **244** connects to the first rod **242**. The second rod **244** may pass through the through hole **232** from the first surface **212** to the second surface **214**. The wafer **12** may be sandwiched in the first rod **242** and the base **210**.

The shape of the wafer clamp **240** is not limited. In the embodiment of this invention, the wafer clamp **240** is in a shape like a letter L, wherein an included angle between the first rod **242** and the second rod **244** is smaller than 180 degrees. Additionally, the wafer clamp **240** may be in a shape like a letter T, etc.

The spring **246** connected to the second rod **244** of the wafer clamp **240** and the base **210** to provide the first rod **242** a force toward the first surface **212** of the base **210**. In particular, the spring **246** may connect the second rod **244** and a region near the opening of the through hole **232** on the second surface **214** of the base **210**. Additionally, the spring **246** may

connect the second rod **244** and an inner surface of the through hole **232**. In the embodiment of this invention, the spring **246** is pivoted on the part of the second rod **244** protruded out of the through hole **232**, wherein two ends of the spring **234** connects the second rod **244** and a region near the opening of the through hole **232** on the second surface **214** of the base **210**.

Since the wafer clamp **240** is connected to the base **210** via the spring **234**, the first rod **242** may rotate around the base **210** on the first surface **212**. Therefore, the first rod **242** may rotate to let part thereof protrude over an edge of the cavity **220**.

When installing the wafer **12**, the first rod **242** may rotate away from the opening of the cavity **220** to allow the wafer **12** pass through. The wafer **12** may be placed on the first surface **212** of the base **210** to be aligned to the mask **10**. Then, the first rod **242** may rotate to protrude over an edge of the cavity **220** to let the wafer **12** be sandwiched in the first rod **242** and the base **210**. Due to the thickness of the wafer **12**, the wafer clamp **240** may move to press the spring **246**, which may generate a spring force. The spring **246** may pull the first rod **242** moving toward or against the first surface **212**. In the embodiment of this invention, the wafer **12** may be clamped by the first rod **242** and the base **210**.

The spring force may be determined by an elastic modulus of the spring **246**. To adjust the spring force, the fixture **200** has a knob **248** to change the elastic modulus of the spring **246**. The knob **248** connects the spring **246** and is fastened on an end of the second rod **244**. In particular, the knob **248** connects an end of the spring **246**, and the other end of the spring **246** is fastened on the base **210**. When the knob **248** is turned, it may tension the spring **246**, and furthermore the elastic modulus of the spring **246** may be changed. In other words, turning the knob **248** to loose or tension the spring **246** may change the elastic modulus of the spring **246**.

Please refer to FIG. **3**. FIG. **3** is a three-dimensional view of an immersion lithography apparatus **300** according to another embodiment of this invention. The immersion lithography apparatus **300** may be used to perform immersion inclined lithography process. During the immersion inclined lithography process, the mask **10** and the wafer **12** may be immersed in liquid **120**, and the principal plane of the wafer **12** is not perpendicular to the main direction of a light beam. Therefore, the wafer **12** may have three-dimensional micro-structures with inclined flanks after the immersion inclined lithography process.

The immersion lithography apparatus **300** has a light source **310**, a filter **320**, a tank **100**, and a fixture **200**. The tank **100** comprises a container **110**, a platform **120**, and a roller **140**. The tank **100** is described above.

Please refer to FIG. **1B** and FIG. **3** at the same time. The light source **310** may be disposed suspending above the tank **100** facing the opening of the container **110**. The light source **310** may generate ultraviolet light to incident on the mask **10** and the wafer **12** via the exposing hole **230** on the fixture **200**. The wavelengths of the ultraviolet light generated from the light source **310** are from about 320 nanometers (referred to as nm) to about 436 nm. In the embodiment of this invention, the distribution of the wavelengths of the ultraviolet light has three peak values, which are about 365 nm, about 405 nm, and about 436 nm.

Diffraction may occur when the ultraviolet light encounters the photoresist layer on the wafer **12**, which may expand the area of the exposed region on the photoresist layer. Since the ultraviolet light has different wavelengths, the expanded area of the exposed region may not be controllable. To avoid the above problem, the immersion lithography apparatus **300** has a filter **320** to block part of the ultraviolet light, especially the ultraviolet light with shorter wavelength. The filter **320** is interposed in a path of the ultraviolet light between the light source **310** and the fixture **200**.

In the embodiment of this invention, the filter **320** may block the ultraviolet light with shorter wavelengths, which are from about 300 nm to about 370 nm. Therefore, the ultraviolet light reached the photoresist layer on the wafer **12** may have wavelengths from about 370 nm to about 450 nm.

As the above, the distribution of the wavelengths of the ultraviolet light in the embodiment of this invention has three peak values, which are about 365 nm, about 405 nm, and about 436 nm. The filter **320** may block part of the ultraviolet light, and the distribution of the wavelengths of the remaining ultraviolet light has two peak values, which are about 405 nm, and about 436 nm.

The wafer **12** has the photoresist layer on the surface thereof facing the mask **10**. Those skilled in the art should know exposing and developing processes and how the mask **10** and the photoresist work in the processes. Different photoresist material may be sensitive to different wavelengths. Take SU-8 type photoresist as an example, the SU-8 type photoresist is sensitive to the ultraviolet light with wavelengths about 405 nm and is insensitive to the ultraviolet light wavelengths about 436 nm. In the embodiment of this invention, the photoresist layer on the wafer **12** is SU-8. Since the light sensitivity of the photoresist, the distribution of the wavelength of the ultraviolet light causing photoreaction may have one peak value, which is about 405 nm.

Additionally, when light travels from a medium to another, refraction may occur. At the boundary between the media, the wave's phase velocity is changed, usually causing a change of direction. According to Snell's law, the angle of incidence and refraction is equivalent to the opposite ratio of the refraction indexes of the media. When the difference between the refraction indexes of the media is smaller, the angle difference between incidence and refraction is smaller.

During the immersion inclined lithography process, the principle plane of the wafer **12** may not be perpendicular to the main direction of a light beam to form three-dimensional micro-structures with inclined flanks. The ultraviolet light may travel from air, mask **10**, etc. to the photoresist layer on the wafer **12**. The included angle between the light beam and the wafer **12** may be affected by the refraction indexes of the above media.

For example, the refraction index of air is about 1. A transparent region on the mask **10** made from silicide may have a refraction index about 1.45. In general, refraction indexes of photoresist materials are from about 1.4 to about 1.8, wherein a refraction index of the SU-8 type photoresist is about 1.67. When the included angle between the incident light beam and the mask **10** is about 90 degrees, the angle of refraction is about 43.6 degrees. At the boundary between the mask **10** and the photoresist layer, the included angle between the light beam and the photoresist layer may be 43.6 degrees, and the angle of refraction is about 36.7 degrees. Therefore, the inclined angle of the micro-structure may be limited because the difference of the refractive indexes between the media is large.

To solve the above problem, the immersion lithography apparatus **300** has the liquid **120** to reduce the difference of the refractive indexes between the media. The liquid **120** is filled in the container **110**. The platform **130**, the fixture **200**, the mask **10**, and the wafer **12** clamped thereon may be immersed in the liquid **120**.

The refractive index of the liquid **120** is similar to the refractive index of the photoresist layer on the wafer **12**. In the

embodiment of this invention, the refractive index of the liquid **120** is ranging from about 1.4 to about 1.8. In a preferred embodiment, the refractive index of the liquid **120** is ranging from about 1.5 to about 1.7. The difference of the refractive indexes between the liquid **120** and the photoresist layer is small. The liquid **120** is transparent and may not react with the photoresist layer. The liquid **120** may be glycerin or oil. In the embodiment of this invention, the liquid **120** is glycerin, wherein the refractive index of the liquid **120** is equal to the refractive index of the photoresist layer on the wafer **12**.

On other hand, the platform **130** of the immersion lithography apparatus **300** may be inclined to let the light beam not perpendicular to the wafer **12**. Therefore, the light beam is normal incidence from air to the liquid **120**, wherein the angles of incidence and refraction are about the same. The included angle between the mask **10** and the light beam is about equal to the inclined angle of the platform **130**. Therefore, the light beam is inclined incidence on the mask **10** and the wafer **12**. Since the refractive index of the liquid **120** is similar to the refractive index of the photoresist layer on the wafer **12**, the angles of incidence and refraction may be about the same.

In the embodiment of this invention, the immersion lithography apparatus **300** has an aligning device **330** operated for aligning the mask **10** and the wafer **12**. The aligning device **330** is disposed next to the immersion lithography apparatus **300**.

The aligning device **330** has a pedestal **332** for supporting the wafer **12**, and a shelf **334** for supporting the fixture **200**. The shelf **334** is suspended above the pedestal **332** and aligns to the pedestal **332**. When the fixture **200** is placed on the shelf **334**, the wafer **12** on the pedestal **332** may be moved to align to the mask **10** clamped on the fixture **200**.

The aligning device **330** has two sets of cameras to capture images of the mask **10** and the wafer **12** from different directions, which may help adjust the alignment of the mask **10** and the wafer **12**.

In particular, at least a first camera **340** is disposed suspended above the shelf **334**. The first camera **340** aligns to the shelf **334** and the pedestal **332**. The first camera **340** may capture images of the mask **10** and the wafer **12**, which may be top views of the mask **10** and the wafer **12**.

At least a second camera **350** is embedded in the pedestal **332**. The second camera **350** may capture images of the mask **10** and the wafer **12**, which may be bottom views of the mask **10** and the wafer **12**. In the embodiment of this invention, the second camera **350** has an optic fiber **352** embedded in the pedestal **332**. The optic fiber **352** has two ends, wherein one of the ends connects the second camera **350** and the other end is exposed on the pedestal **332**.

The first camera **340** and the second camera **350** are electrically connected to a monitor **360**. The monitor **360** may be operated to display the images captured from the first camera **340** and the second camera **350**.

In the foregoing, the platform **130** of the tank **100** may be inclined by the roller **140** to perform the immersion inclined lithography process. The liquid **120** filled in the container **110** has the refraction index similar to the photoresist layer on the wafer **12**, which may help reduce the change of the angle due to refraction.

Although the present invention has been described in considerable detail with reference to certain embodiments thereof, other embodiments are possible. Therefore, the spirit and scope of the appended claims should not be limited to the description of the embodiments contained herein.

It will be apparent to those skilled in the art that various modifications and variations can be made to the structure of the present invention without departing from the scope or spirit of the invention. In view of the foregoing, it is intended that the present invention cover modifications and variations of this invention provided they fall within the scope of the following claims.

What is claimed is:

1. An immersion lithography apparatus, comprising:

a container comprising a bottom plate, a plurality of side plates connected to one another, and a bearing hole penetrated through one of the side plates, wherein the side plates surround and connect all edges of the bottom plate;

at least a liquid filled in the container having a refractive index ranging from about 1.4 to about 1.8;

a platform located in the container and immersed in the liquid, the platform comprising a pair of axles fastened separately on opposite sides thereof, the axles being parallel to the bottom plate and one of the axles being passing through the bearing hole;

a fixture mounted on the platform and immersed in the liquid for clamping at least a mask and a wafer;

a roller disposed outside the container, the roller being connected to the axle passing through the bearing hole and operated to rotate the connected axle to incline the platform;

a light source for generating ultraviolet light to incident on the mask and the wafer; and

a filter located in a path of the ultraviolet light interposed between the light source and the fixture.

2. The immersion lithography apparatus of claim **1**, wherein the filter blocks the ultraviolet light having wavelength from about 300 nanometers to about 370 nanometers.

3. The immersion lithography apparatus of claim **1**, wherein the fixture comprises:

a base comprising a first surface and a second surface, which are a pair of opposite surfaces of the base;

a cavity disposed in the middle of the first surface for containing the wafer;

an exposing hole disposed in the cavity and penetrated through the base for the ultraviolet light passing through; and

a plurality of first clamps disposed surrounding the cavity, each clamp has two ends, wherein one of the ends is fastened on the base and the other end protruded over an edge of the cavity for contacting the mask.

4. The immersion lithography apparatus of claim **3**, wherein the fixture further comprises:

At least a through hole penetrated through the base out of the cavity;

At least a second clamp has a first rod extending parallel to the first surface and a second rod connected to the first rod and passing the through hole from the first surface to the second surface, wherein the wafer is sandwiched in the first rod and the base; and

a spring connected to the second rod and the base.

5. The immersion lithography apparatus of claim **4**, wherein the fixture further comprises a knob connected to the spring to tension the spring.

6. The immersion lithography apparatus of claim **1**, wherein the refractive index of the liquid is ranging from about 1.5 to about 1.7.

7. The immersion lithography apparatus of claim **1**, further comprising an aligning device operated for aligning the mask and the wafer, the aligning device comprising:

a pedestal for supporting the wafer;

a shelf suspended above and aligning to the pedestal for supporting the fixture;

at least a first camera suspended above the shelf and aligning to the shelf and the pedestal for capturing an image of the mask and the wafer; and

at least a second camera embedded in the pedestal and aligning to the shelf and the pedestal for capturing an image of the mask and the wafer.

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