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(54) **APPARATUS AND METHOD FOR MAINTAINING IMMERSION FLUID IN THE GAP UNDER THE PROJECTION LENS DURING WAFER EXCHANGE IN AN IMMERSION LITHOGRAPHY MACHINE**

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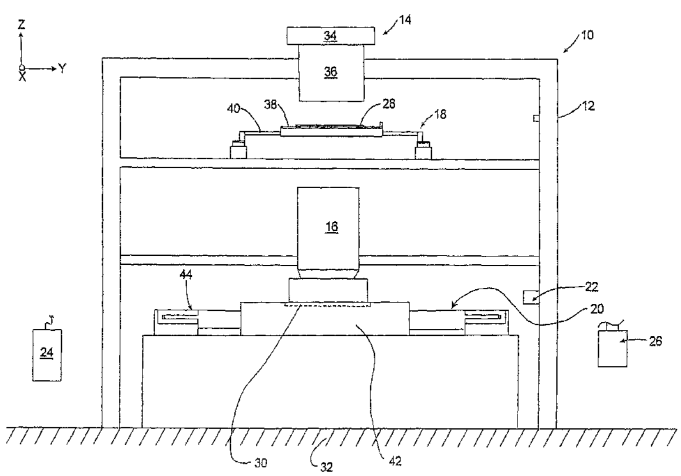
(57) **ABSTRACT**

An immersion exposure apparatus and method exposes a substrate with an exposure beam via an optical element and immersion liquid. A table mounts the substrate. A member is positionable under the optical element. A holding member is arranged to hold the member such that the member is located opposed to the optical element. Each of the table and the member are configured to maintain the immersion liquid below the optical element when located opposed to the optical element. The member is positionable to be away from a position below the optical element when the substrate, mounted on the table, is located opposed to the optical element. The table is movable to be away from below the optical element while the member is held opposed to the optical element.

30 Claims, 9 Drawing Sheets



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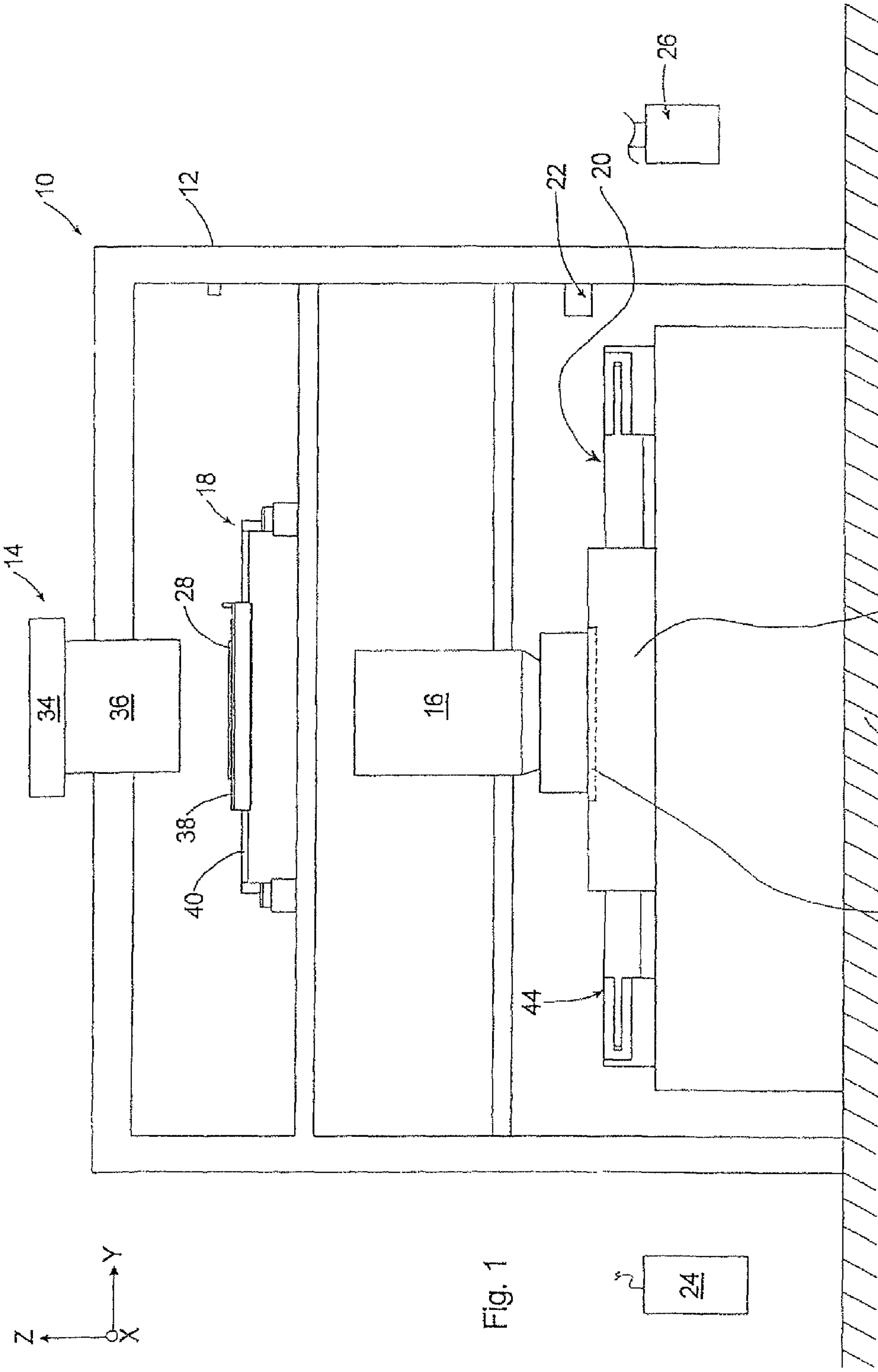


Fig. 1

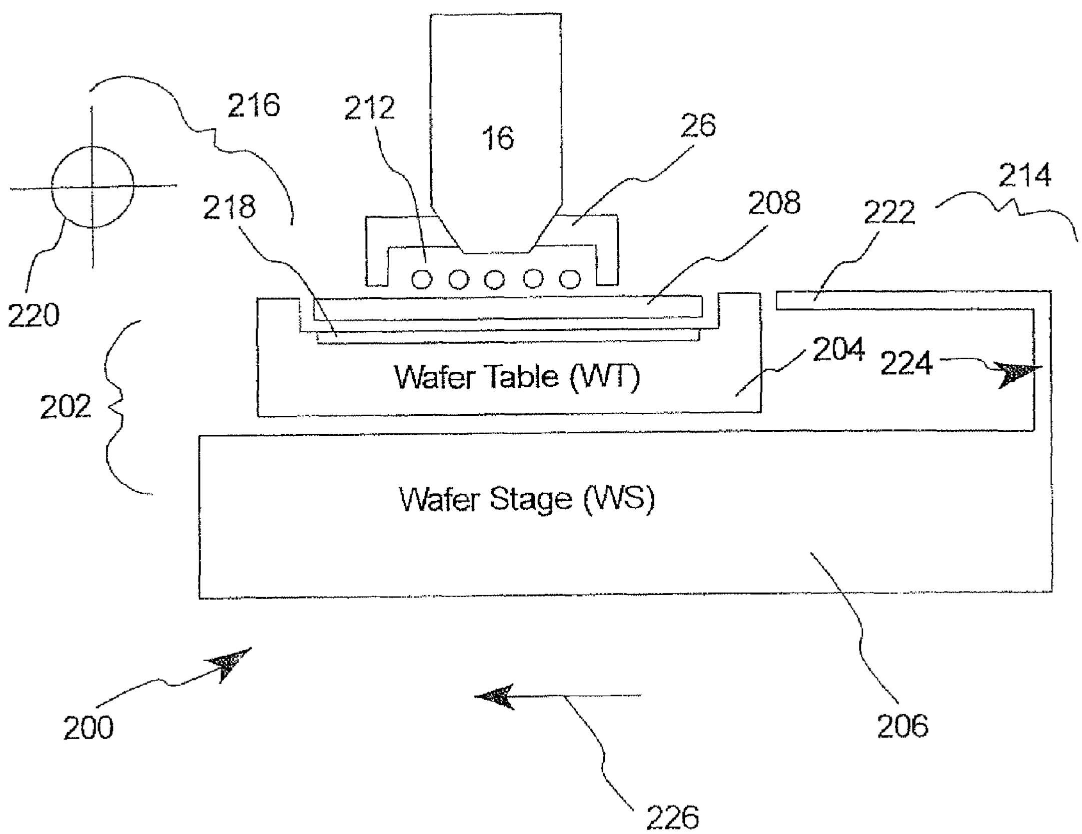
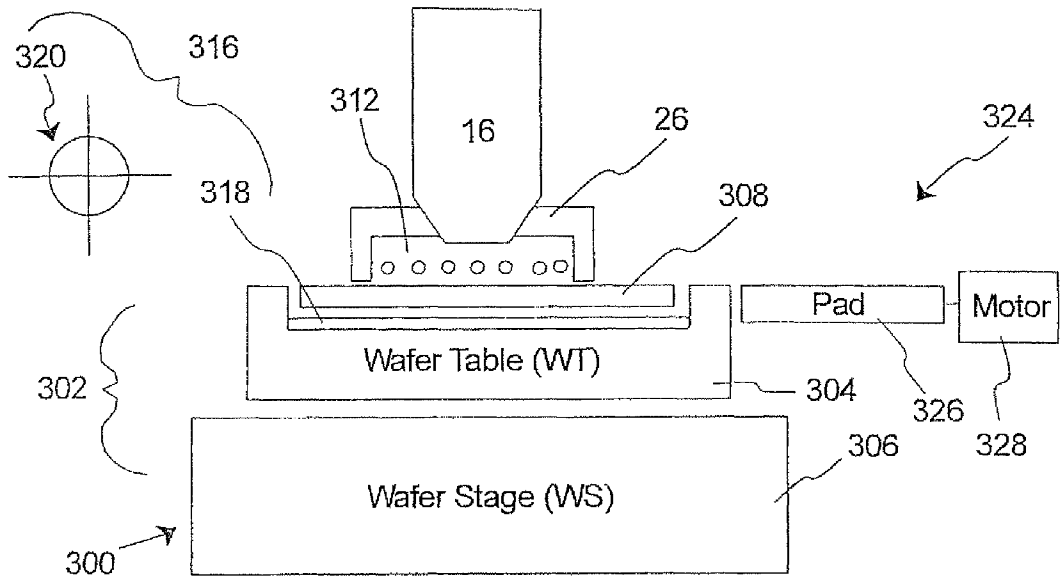
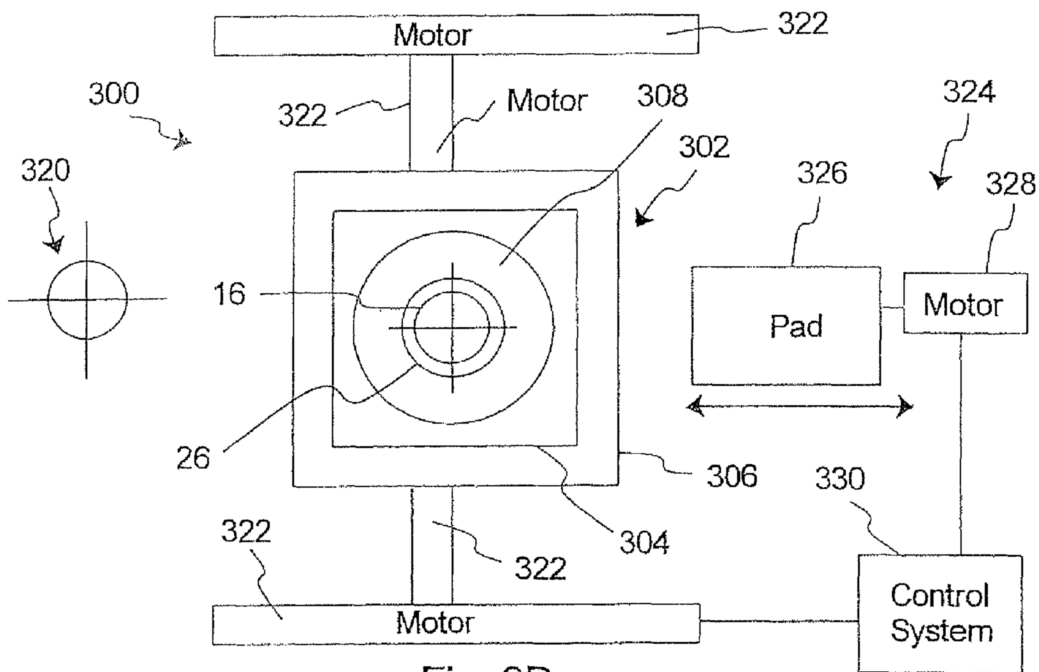

216
212
16
26
214
218
208
222
220
204
224
Wafer Table (WT)
202
Wafer Stage (WS)
200
206
226

Fig. 2


320
316
312
16
26
324
318
308
Pad
Motor
Wafer Table (WT)
302
304
326
328
306
Wafer Stage (WS)
300
Fig. 3A


Motor
322
300
322
Motor
308
324
302
320
326
328
16
Motor
Pad
26
306
330
322
304
322
Control System
Motor
Fig. 3B

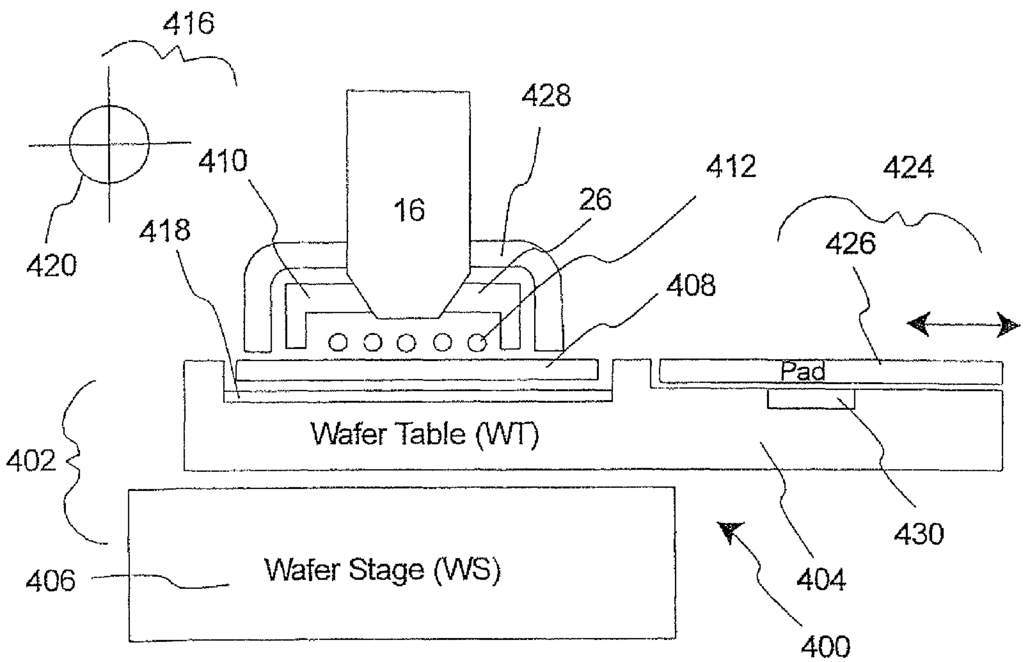

416
428
410
16
26
412
424
426
420
418
408
Pad
Wafer Table (WT)
402
430
Wafer Stage (WS)
406
404
400

Fig. 4A

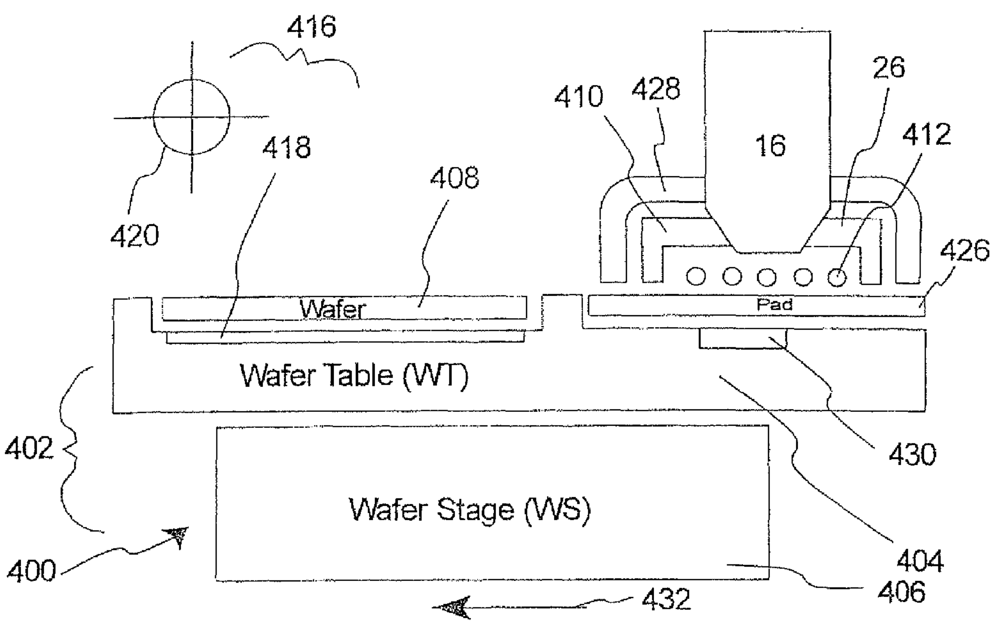

416
26
410
428
16
412
418
420
408
426
Wafer
Pad
Wafer Table (WT)
430
402
Wafer Stage (WS)
404
400
406
432

Fig. 4B

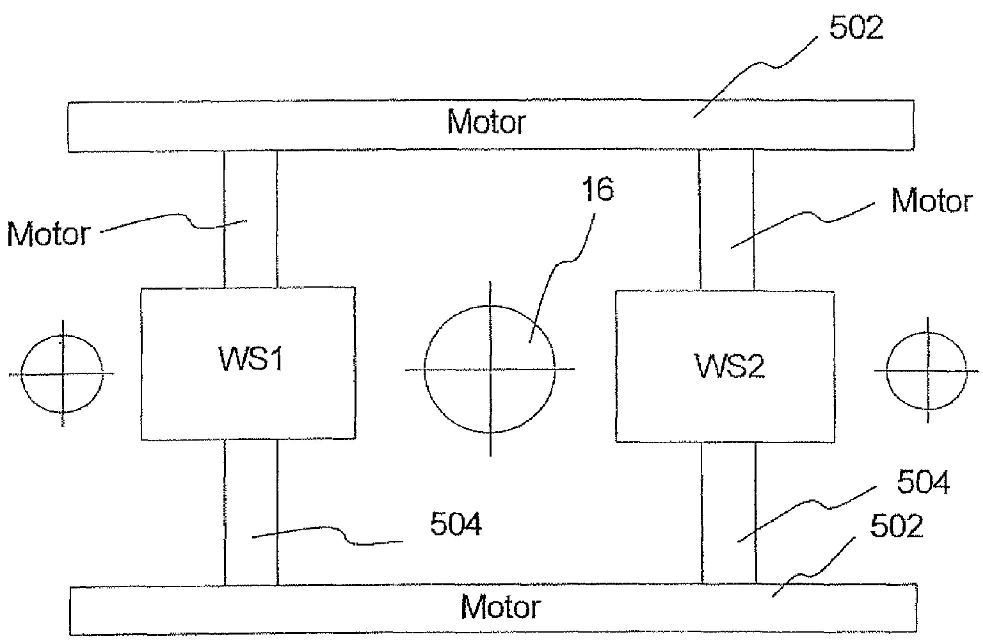

502
Motor
16
Motor
Motor
WS1
WS2
504
504
502
Motor

Fig. 5A

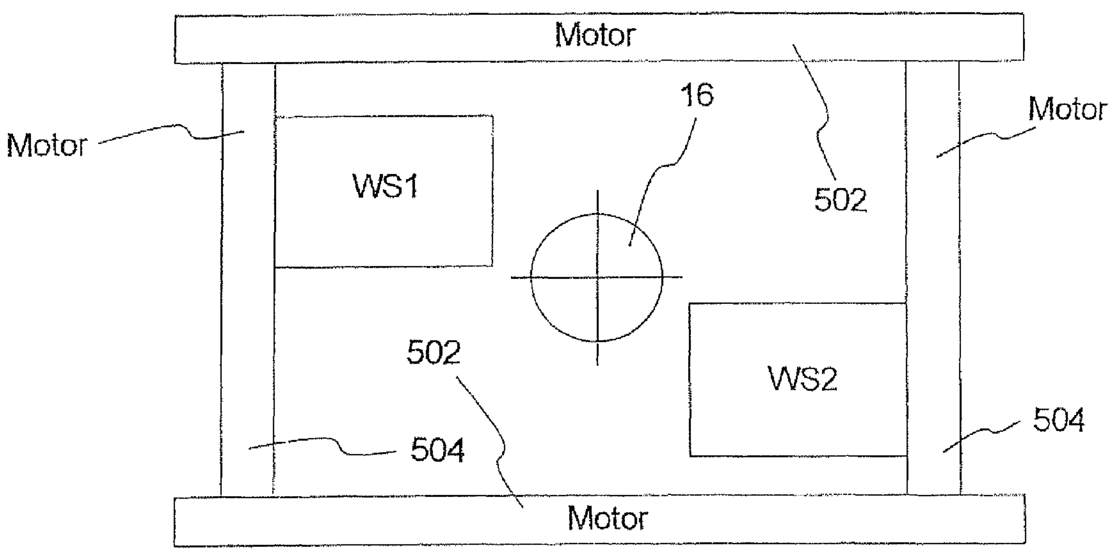

Motor
16
Motor
Motor
WS1
502
502
WS2
504
504
Motor

Fig. 5B

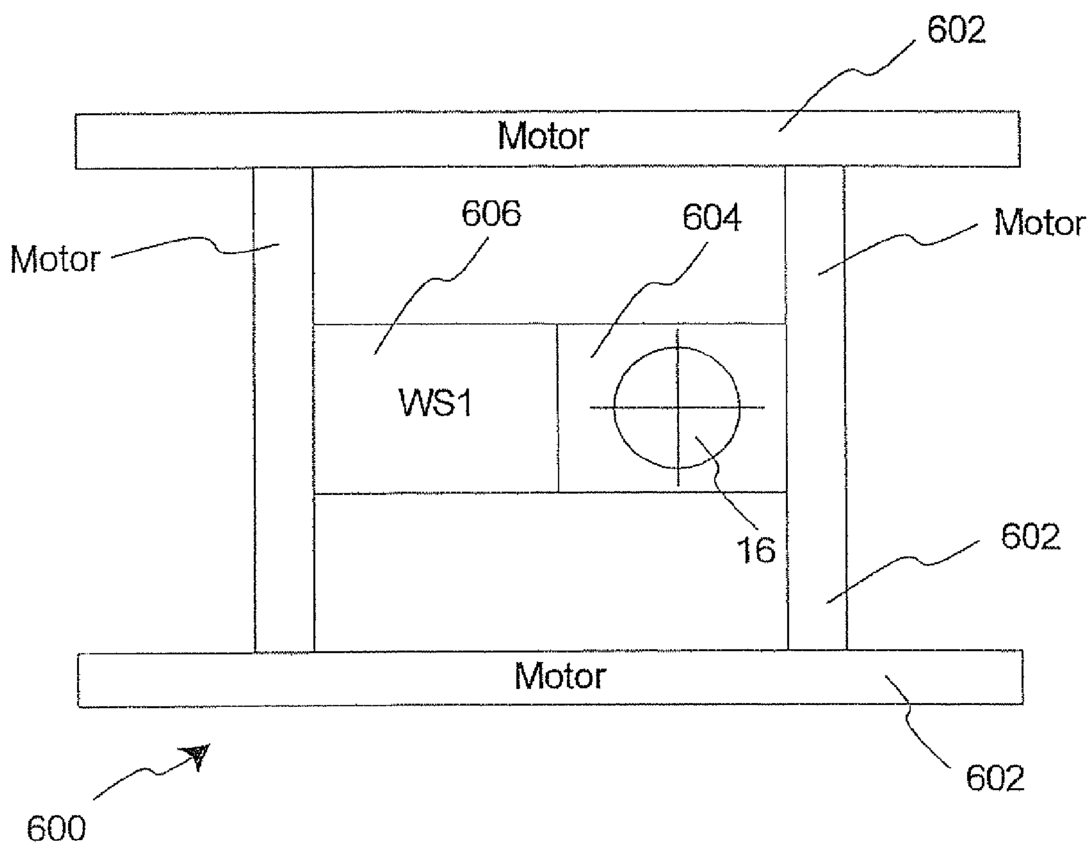


Fig. 6A

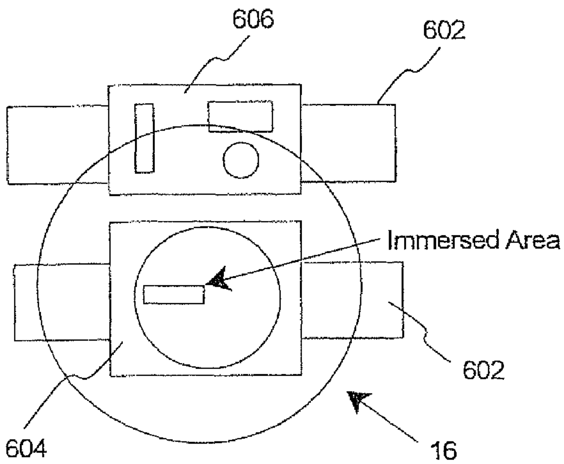


Fig. 6B

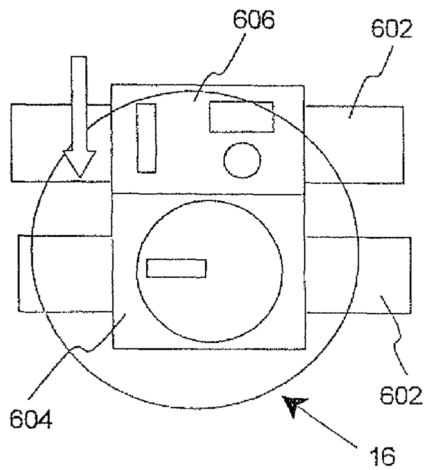


Fig. 6C

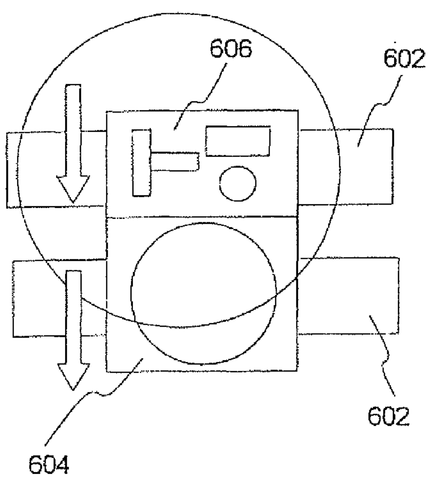


Fig. 6D

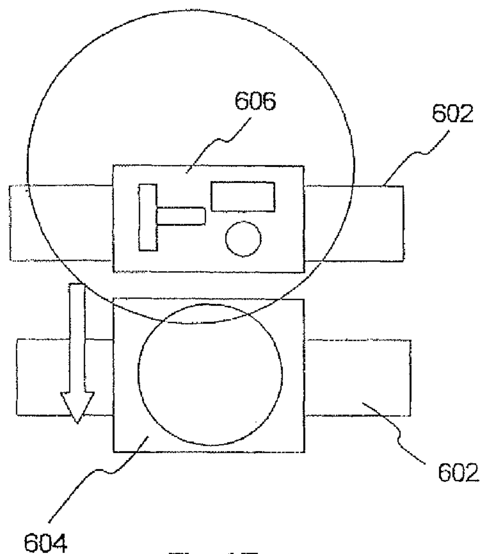


Fig. 6E

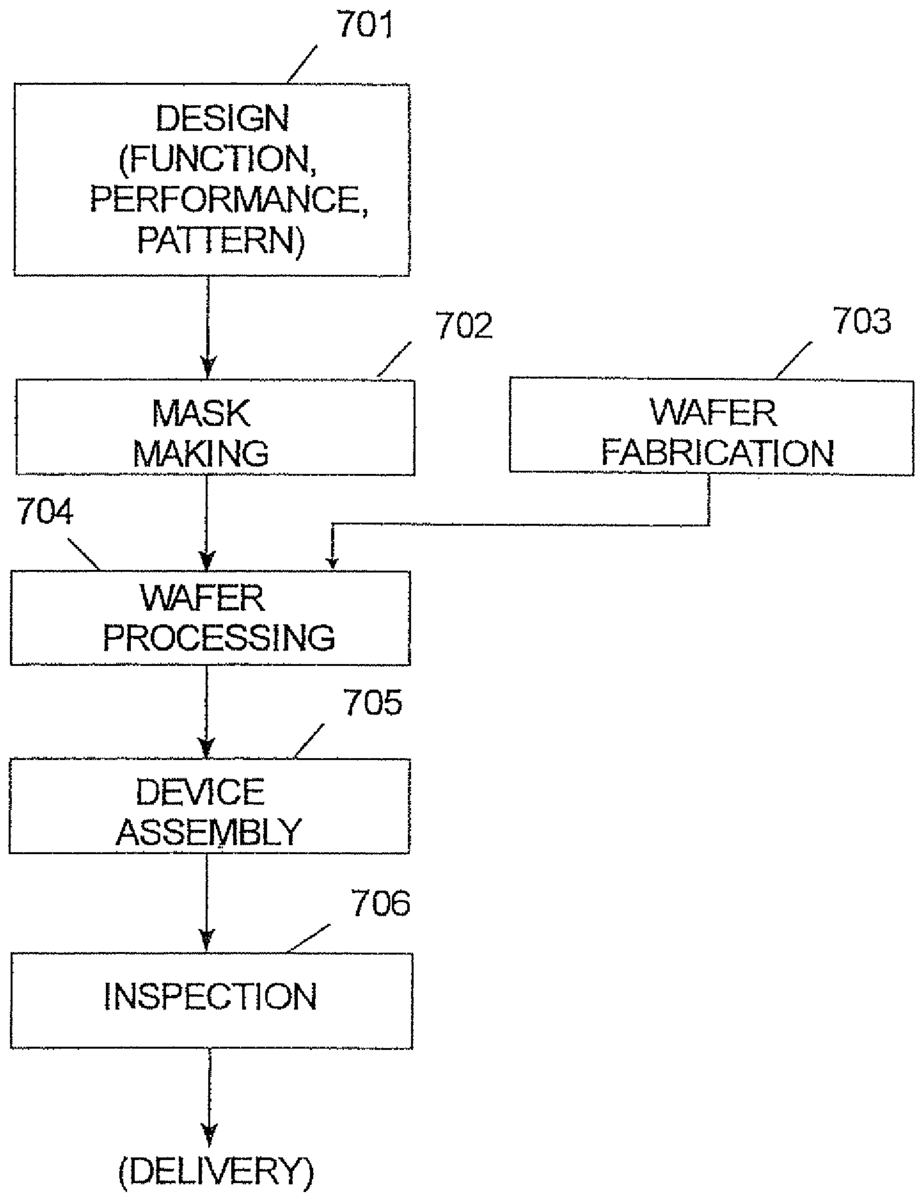

701
DESIGN (FUNCTION, PERFORMANCE, PATTERN)
702
MASK MAKING
703
WAFER FABRICATION
704
WAFER PROCESSING
705
DEVICE ASSEMBLY
706
INSPECTION
(DELIVERY)

Fig. 7A

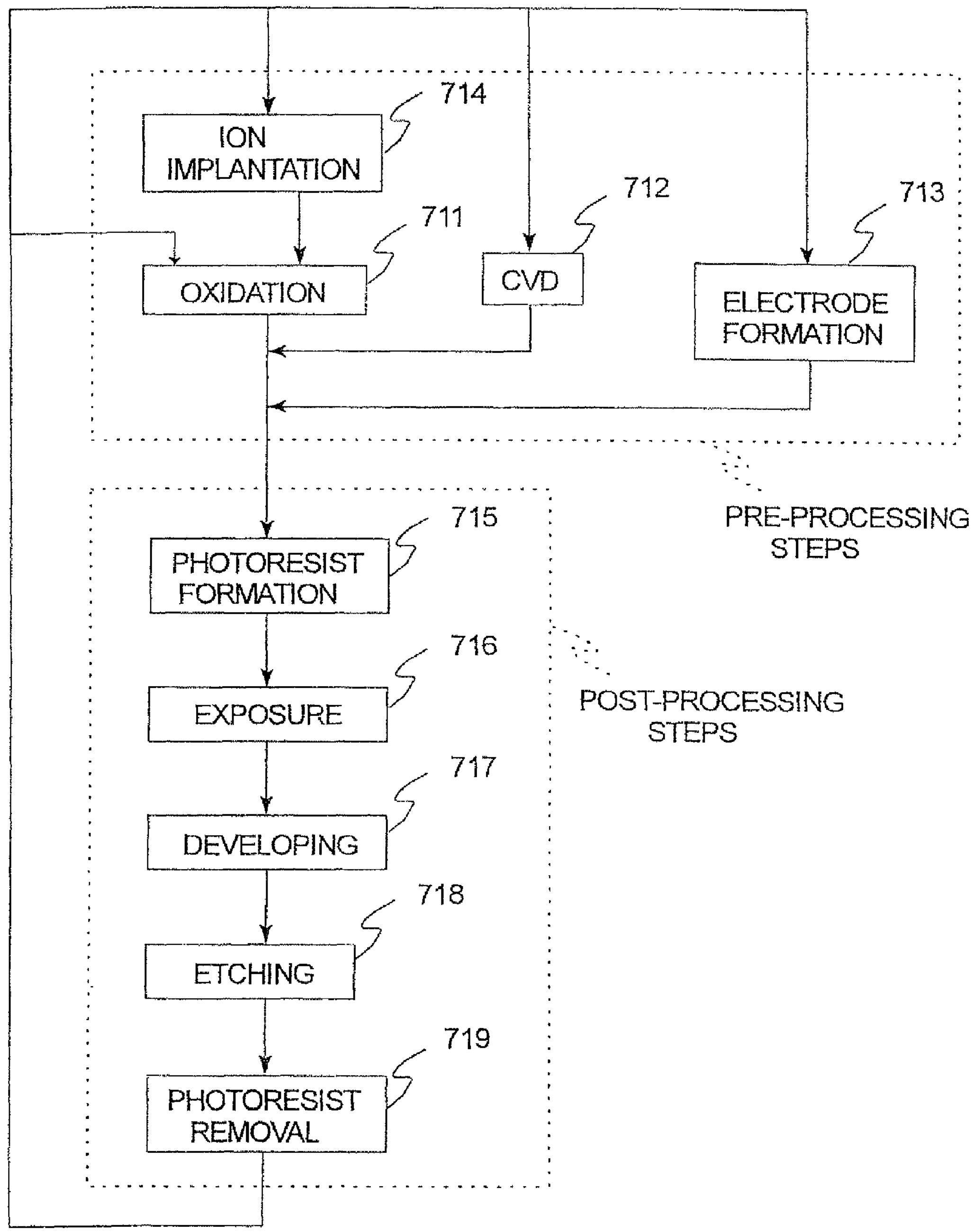

714
ION IMPLANTATION
711
OXIDATION
712
CVD
713
ELECTRODE FORMATION
PRE-PROCESSING STEPS
715
PHOTORESIST FORMATION
716
EXPOSURE
717
DEVELOPING
718
ETCHING
719
PHOTORESIST REMOVAL
POST-PROCESSING STEPS

Fig. 7B

APPARATUS AND METHOD FOR MAINTAINING IMMERSION FLUID IN THE GAP UNDER THE PROJECTION LENS DURING WAFER EXCHANGE IN AN IMMERSION LITHOGRAPHY MACHINE

RELATED APPLICATIONS

This is a Divisional of U.S. patent application Ser. No. 11/822,804 filed Jul. 10, 2007, which in turn is a Divisional of U.S. patent application Ser. No. 11/237,721 filed Sep. 29, 2005 (now U.S. Pat. No. 7,372,538), which is a Continuation of International Application No. PCT/IB2004/001259 filed Mar. 17, 2004, which claims the benefit of U.S. Provisional Application No. 60/462,499 filed on Apr. 11, 2003. The entire disclosures of the prior applications are incorporated herein by reference in their entireties.

BACKGROUND

Lithography systems are commonly used to transfer images from a reticle onto a semiconductor wafer during semiconductor processing. A typical lithography system includes an optical assembly, a reticle stage for holding a reticle defining a pattern, a wafer stage assembly that positions a semiconductor wafer, and a measurement system that precisely monitors the position of the reticle and the wafer. During operation, an image defined by the reticle is projected by the optical assembly onto the wafer. The projected image is typically the size of one or more die on the wafer. After an exposure, the wafer stage assembly moves the wafer and then another exposure takes place. This process is repeated until all the die on the wafer are exposed. The wafer is then removed and a new wafer is exchanged in its place.

Immersion lithography systems utilize a layer of immersion fluid that completely fills a gap between the optical assembly and the wafer during the exposure of the wafer. The optic properties of the immersion fluid, along with the optical assembly, allow the projection of smaller feature sizes than is currently possible using standard optical lithography. For example, immersion lithography is currently being considered for next generation semiconductor technologies including 65 nanometers, 45 nanometers, and beyond. Immersion lithography therefore represents a significant technological breakthrough that will likely enable the continued use of optical lithography for the foreseeable future.

After a wafer is exposed, it is removed and exchanged with a new wafer. As currently contemplated in immersion systems, the immersion fluid would be removed from the gap and then replenished after the wafer is exchanged. More specifically, when a wafer is to be exchanged, the fluid supply to the gap is turned off, the fluid is removed from the gap (i.e., by vacuum), the old wafer is removed, a new wafer is aligned and placed under the optical assembly, and then the gap is re-filled with fresh immersion fluid. Once all of the above steps are complete, exposure of the new wafer can begin.

Wafer exchange with immersion lithography as described above is problematic for a number of reasons. The repeated filling and draining of the gap may cause variations in the immersion fluid and may cause bubbles to form within the immersion fluid. Bubbles and the unsteady fluid may interfere with the projection of the image on the reticle onto the wafer, thereby reducing yields. The overall process also involves many steps and is time consuming, which reduces the overall throughput of the machine.

An apparatus and method for maintaining immersion fluid in the gap adjacent to the projection lens when the wafer stage

moves away from the projection lens, for example during wafer exchange, is therefore needed.

SUMMARY

An apparatus and method maintain immersion fluid in the gap adjacent to the projection lens in a lithography machine. The apparatus and method include an optical assembly that projects an image onto a work piece and a stage assembly including a work piece table that supports the work piece adjacent to the optical assembly. An environmental system is provided to supply and remove an immersion fluid from the gap. After exposure of the work piece is complete, an exchange system removes the work piece and replaces it with a second work piece. An immersion fluid containment system is provided to maintain the immersion fluid in the gap when the work piece table moves away from the projection lens. The gap therefore does not have to be refilled with immersion fluid when the first work piece is replaced with a second work piece.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will be described in conjunction with the following drawings of exemplary embodiments in which like reference numerals designate like elements, and in which:

FIG. **1** is an illustration of an immersion lithography machine having features of the invention;

FIG. **2** is a cross section of an immersion lithography machine according to one embodiment of the invention;

FIGS. **3**A and **3**B are a cross section and a top down view of an immersion lithography machine according to another embodiment of the invention;

FIGS. **4**A and **4**B are cross section views of an immersion lithography machine according to another embodiment of the invention;

FIGS. **5**A and **5**B are top down views of two different twin wafer stages according to other embodiments of the invention;

FIG. **6**A is a top down view of a twin stage lithography machine according to another embodiment of the invention;

FIGS. **6**B-**6**E are a series of diagrams illustrating a wafer exchange according to the invention;

FIG. **7**A is a flow chart that outlines a process for manufacturing a work piece in accordance with the invention; and

FIG. **7**B is a flow chart that outlines work piece processing in more detail.

DETAILED DESCRIPTION OF EMBODIMENTS

FIG. **1** is a schematic illustration of a lithography machine **10** having features of the invention. The lithography machine **10** includes a frame **12**, an illumination system **14** (irradiation apparatus), an optical assembly **16**, a reticle stage assembly **18**, a work piece stage assembly **20**, a measurement system **22**, a control system **24**, and a fluid environmental system **26**. The design of the components of the lithography machine **10** can be varied to suit the design requirements of the lithography machine **10**.

In one embodiment, the lithography machine **10** is used to transfer a pattern (not shown) of an integrated circuit from a reticle **28** onto a semiconductor wafer **30** (illustrated in phantom). The lithography machine **10** mounts to a mounting base **32**, e.g., the ground, a base, or floor or some other supporting structure.

In various embodiments of the invention, the lithography machine **10** can be used as a scanning type photolithography system that exposes the pattern from the reticle **28** onto the wafer **30** with the reticle **28** and the wafer **30** moving synchronously. In a scanning type lithographic machine, the reticle **28** is moved perpendicularly to an optical axis of the optical assembly **16** by the reticle stage assembly **18**, and the wafer **30** is moved perpendicularly to the optical axis of the optical assembly **16** by the wafer stage assembly **20**. Scanning of the reticle **28** and the wafer **30** occurs while the reticle **28** and the wafer **30** are moving synchronously.

Alternatively, the lithography machine **10** can be a step-and-repeat type photolithography system that exposes the reticle **28** while the reticle **28** and the wafer **30** are stationary. In the step and repeat process, the wafer **30** is in a constant position relative to the reticle **28** and the optical assembly **16** during the exposure of an individual field. Subsequently, between consecutive exposure steps, the wafer **30** is consecutively moved with the wafer stage assembly **20** perpendicularly to the optical axis of the optical assembly **16** so that the next field of the wafer **30** is brought into position relative to the optical assembly **16** and the reticle **28** for exposure. Following this process, the images on the reticle **28** are sequentially exposed onto the fields of the wafer **30**, and then the next field of the wafer **30** is brought into position relative to the optical assembly **16** and the reticle **28**.

However, the use of the lithography machine **10** provided herein is not necessarily limited to a photolithography for semiconductor manufacturing. The lithography machine **10**, for example, can be used as an LCD photolithography system that exposes a liquid crystal display work piece pattern onto a rectangular glass plate or a photolithography system for manufacturing a thin film magnetic head. Accordingly, the term "work piece" is generically used herein to refer to any device that may be patterned using lithography, such as but not limited to wafers or LCD substrates.

The apparatus frame **12** supports the components of the lithography machine **10**. The apparatus frame **12** illustrated in FIG. **1** supports the reticle stage assembly **18**, the wafer stage assembly **20**, the optical assembly **16** and the illumination system **14** above the mounting base **32**.

The illumination system **14** includes an illumination source **34** and an illumination optical assembly **36**. The illumination source **34** emits a beam (irradiation) of light energy. The illumination optical assembly **36** guides the beam of light energy from the illumination source **34** to the optical assembly **16**. The beam illuminates selectively different portions of the reticle **28** and exposes the wafer **30**. In FIG. **1**, the illumination source **34** is illustrated as being supported above the reticle stage assembly **18**. Typically, however, the illumination source **34** is secured to one of the sides of the apparatus frame **12** and the energy beam from the illumination source **34** is directed to above the reticle stage assembly **18** with the illumination optical assembly **36**.

The illumination source **34** can be a g-line source (436 nm), an i-line source (365 nm), a KrF excimer laser (248 nm), an ArF excimer laser (193 nm) or a F_2 laser (157 nm). Alternatively, the illumination source **34** can generate an x-ray.

The optical assembly **16** projects and/or focuses the light passing through the reticle **28** to the wafer **30**. Depending upon the design of the lithography machine **10**, the optical assembly **16** can magnify or reduce the image illuminated on the reticle **28**. The optical assembly **16** need not be limited to a reduction system. It could also be a 1× or greater magnification system.

Also, with an exposure work piece that employs vacuum ultra-violet radiation (VUV) of wavelength 200 nm or lower, use of a catadioptric type optical system can be considered. Examples of a catadioptric type of optical system are disclosed in Japanese Laid-Open Patent Application Publication No. 8-171054 and its counterpart U.S. Pat. No. 5,668,672, as well as Japanese Laid-Open Patent Publication No. 10-20195 and its counterpart U.S. Pat. No. 5,835,275. In these cases, the reflecting optical system can be a catadioptric optical system incorporating a beam splitter and concave mirror. Japanese Laid-Open Patent Application Publication No. 8-334695 and its counterpart U.S. Pat. No. 5,689,377 as well as Japanese Laid-Open Patent Application Publication No. 10-3039 and its counterpart U.S. patent application Ser. No. 873,605 (Application Date: Jun. 12, 1997) also use a reflecting-refracting type of optical system incorporating a concave mirror, etc., but without a beam splitter, and also can be employed with this invention. The disclosures of the above-mentioned U.S. patents and applications, as well as the Japanese Laid-Open patent application publications are incorporated herein by reference in their entireties.

The reticle stage assembly **18** holds and positions the reticle **28** relative to the optical assembly **16** and the wafer **30**. In one embodiment, the reticle stage assembly **18** includes a reticle stage **38** that retains the reticle **28** and a reticle stage mover assembly **40** that moves and positions the reticle stage **38** and reticle **28**.

Each stage mover assembly **40**, **44** can move the respective stage **38**, **42** with three degrees of freedom, less than three degrees of freedom, or more than three degrees of freedom. For example, in alternative embodiments, each stage mover assembly **40**, **44** can move the respective stage **38**, **42** with one, two, three, four, five or six degrees of freedom. The reticle stage mover assembly **40** and the work piece stage mover assembly **44** can each include one or more movers, such as rotary motors, voice coil motors, linear motors utilizing a Lorentz force to generate drive force, electromagnetic movers, planar motors, or some other force movers.

In photolithography systems, when linear motors (see U.S. Pat. No. 5,623,853 or 5,528,118 which are incorporated by reference herein in their entireties) are used in the wafer stage assembly or the reticle stage assembly, the linear motors can be either an air levitation type employing air bearings or a magnetic levitation type using Lorentz force or reactance force. Additionally, the stage could move along a guide, or it could be a guileless type stage that uses no guide.

Alternatively, one of the stages could be driven by a planar motor, which drives the stage by an electromagnetic force generated by a magnet unit having two-dimensionally arranged magnets and an armature coil unit having two-dimensionally arranged coils in facing positions. With this type of driving system, either the magnet unit or the armature coil unit is connected to the stage base and the other unit is mounted on the moving plane side of the stage.

Movement of the stages as described above generates reaction forces that can affect performance of the photolithography system. Reaction forces generated by the wafer (substrate) stage motion can be mechanically transferred to the floor (ground) by use of a frame member as described in U.S. Pat. No. 5,528,100 and Japanese Laid-Open Patent Application Publication No. 8-136475. Additionally, reaction forces generated by the reticle (mask) stage motion can be mechanically transferred to the floor (ground) by use of a frame member as described in U.S. Pat. No. 5,874,820 and Japanese Laid-Open Patent Application Publication No. 8-330224. The disclosures of U.S. Pat. Nos. 5,528,100 and 5,874,820 and Japanese Paid-Open Patent Application Publication Nos. 8-136475 and 8-330224 are incorporated herein by reference in their entireties.

The measurement system **22** monitors movement of the reticle **28** and the wafer **30** relative to the optical assembly **16** or some other reference. With this information, the control system **24** can control the reticle stage assembly **18** to precisely position the reticle **28** and the work piece stage assembly **20** to precisely position the wafer **30**. The design of the measurement system **22** can vary. For example, the measurement system **22** can utilize multiple laser interferometers, encoders, mirrors, and/or other measuring devices.

The control system **24** receives information from the measurement system **22** and controls the stage assemblies **18**, **20** to precisely position the reticle **28** and the wafer **30**. Additionally, the control system **24** can control the operation of the components of the environmental system **26**. The control system **24** can include one or more processors and circuits.

The environmental system **26** controls the environment in a gap (not shown) between the optical assembly **16** and the wafer **30**. The gap includes an imaging field. The imaging field includes the area adjacent to the region of the wafer **30** that is being exposed and the area in which the beam of light energy travels between the optical assembly **16** and the wafer **30**. With this design, the environmental system **26** can control the environment in the imaging field. The desired environment created and/or controlled in the gap by the environmental system **26** can vary accordingly to the wafer **30** and the design of the rest of the components of the lithography machine **10**, including the illumination system **14**. For example, the desired controlled environment can be a fluid such as water. Alternatively, the desired controlled environment can be another type of fluid such as a gas. In various embodiments, the gap may range from 0.1 mm to 10 mm in height between top surface of the wafer **30** and the last optical element of the optical assembly **16**.

In one embodiment, the environmental system **26** fills the imaging field and the rest of the gap with an immersion fluid. The design of the environmental system **26** and the components of the environmental system **26** can be varied. In different embodiments, the environmental system **26** delivers and/or injects immersion fluid into the gap using spray nozzles, electro-kinetic sponges, porous materials, etc. and removes the fluid from the gap using vacuum pumps, sponges, and the like. The design of the environmental system **26** can vary. For example, it can inject the immersion fluid at one or more locations at or near the gap. Further, the immersion fluid system can assist in removing and/or scavenging the immersion fluid at one or more locations at or near the work piece **30**, the gap and/or the edge of the optical assembly **16**. For additional details on various environmental systems, see U.S. provisional patent applications 60/462,142 entitled "Immersion Lithography Fluid Control System" filed on Apr. 9, 2003, 60/462,112 entitled "Vacuum Ring System and Wick Ring System for Immersion Lithography" filed on Apr. 10, 2003, 60/500,312 entitled "Noiseless Fluid Recovery With Porous Material" filed on Sep. 3, 2003, and 60/541,329 entitled "Nozzle Design for Immersion Lithography" filed on Feb. 2, 2004, all incorporated by reference herein in their entireties.

Referring to FIG. **2**, a cross section of a lithography machine illustrating one embodiment of the invention is shown. The lithography machine **200** includes an optical assembly **16** and a stage assembly **202** that includes a wafer table **204** and a wafer stage **206**. The wafer table **204** is configured to support a wafer **208** (or any other type of work piece) under the optical assembly **16**. An environmental system **26**, surrounding the optical assembly **16**, is used to supply and remove immersion fluid **212** from the gap between the wafer **208** and the last optical element of the optical assembly **16**. A work piece exchange system **216**, including a wafer loader **218** (i.e., a robot) and an alignment tool **220** (i.e., a microscope and CCD camera), is configured to remove the wafer **208** on the wafer table **204** and replace it with a second wafer. This is typically accomplished using the wafer loader **218** to lift and remove the wafer **208** from the wafer table **204**. Subsequently, the second wafer (not shown) is placed onto the wafer chuck **218**, aligned using the alignment tool **220**, and then positioned under the optical assembly **16** on the wafer table **204**.

With this embodiment, the wafer stage **206** includes an immersion fluid containment system **214** that is configured to maintain the immersion fluid **212** in the gap adjacent to the last optical element of the optical assembly **16** during wafer exchange. The immersion fluid containment system **214** includes a pad **222** that is adjacent to the wafer table **204**. A support member **224**, provided between the pad **222** and the wafer stage **206**, is used to support the pad **222**. The wafer table **204** has a flat upper surface that is coplanar with a surface of the wafer **208**. The pad **222** also has a flat upper surface that is coplanar with the upper surface of the wafer table **204** and the wafer surface. The pad **222** is arranged adjacent to the wafer table **204** with a very small gap (e.g., 0.1-1.0 mm) so that the immersion fluid **212** is movable between the wafer table **204** and the pad **222** without leaking. During a wafer exchange, the wafer stage **206** is moved in the direction of arrow **226** so that the pad **222** is positioned under the optical assembly **16** in place of the wafer table **204**, maintaining the fluid in the gap or maintaining the size of the fluid gap. After the new wafer has been aligned, the wafer stage is moved back to its original position so that the pad **222** is removed from the gap as the second wafer is positioned under the optical assembly **16**. In various embodiments, the pad **222** is disposed continuously adjacent to the wafer table **204** with no gap. Vertical position and/or tilt of the wafer table **204** can be adjusted so that the wafer table surface is coplanar with the pad surface, before the wafer table **204** is moved out from under the optical assembly **16**. Maintaining the gap between the pad **222** and the optical assembly **16** is not limited to just a wafer exchange operation. The pad **222** can be large enough to maintain the immersion fluid **212** in the space between the pad **222** and the optical assembly **16** during an alignment operation or a measurement operation. In those operations, a part of the area occupied by the immersion fluid **212** may be on the upper surface of the wafer table **204**.

Referring to FIGS. **3**A and **3**B, a cross section and a top down view of another immersion lithography machine according to another embodiment of the present invention are shown. The lithography machine **300** includes an optical assembly **16** and a stage assembly **302** that includes a wafer table **304** and a wafer stage **306**. The wafer table **304** is configured to support a wafer **308** (or any other type of work piece) under the optical assembly **16**. An environmental system **26**, surrounding the optical assembly **16**, is used to supply and remove immersion fluid **312** from the gap between the wafer **308** and the lower most optical element of the optical assembly **16**. A work piece exchange system **316**, including a wafer loader **318** and an alignment tool **320**, is configured to remove the wafer **308** on the wafer table **304** and replace it with a second wafer. This is accomplished using the wafer loader **318** to remove the wafer **308** from the wafer table. Subsequently, the second wafer (not shown) is placed onto the wafer chuck **318**, aligned using the alignment tool **320**, and then positioned under the optical assembly **16**. As best illustrated in FIG. **3**B, a set of motors **322** are used to move the wafer assembly **302** including the wafer table **304** and wafer stage **306** in two degrees of freedom (X and Y) during operation. As noted above, the motors **322** can be any type of motors, such as linear motors, rotary motors, voice coil motors, etc.

The immersion lithography machine **300** also includes an immersion fluid containment system **324** that is configured to maintain the immersion fluid **312** in the space below the optical assembly **16** while the wafer table **304** is away from under the optical assembly. The immersion fluid containment system **324** includes a pad **326**, a motor **328**, and a control system **330**. The pad **326** can be positioned adjacent to the optical assembly **16** and the wafer table **304**. The wafer table **304** has a flat upper surface that is coplanar with a surface of the wafer **308**. The pad **326** has a flat upper surface that is coplanar with the upper surface of the wafer table **304** and the wafer surface. The pad **326** is movable in the X and Y directions using the motor **328**, which is controlled by the control system **330**. The motor **328** can be any type of motor as well as the motors **322**. The pad **326** is positioned under the optical assembly **16** when the wafer table **304** (the wafer stage **306**) is away from under the optical assembly **16**. During a wafer exchange, the wafer table **304** moves away from the optical assembly **16**. Simultaneously, the control system **330** directs the motor **328** to move pad **326** under the optical assembly **16**, replacing the wafer table **304**. The pad **326** thus retains the immersion fluid **312** within the gap under the optical assembly **16**. After the new wafer has been aligned using the alignment tool **320**, the wafer table **304** is repositioned under the optical assembly **16**. At the same time, the control system **330** directs the motor **328** to retract the pad **326** from the gap, preventing the escape of the immersion fluid **312**. In the wafer exchange operation, the control system **330** moves the wafer table **304** and the pad **326** with a small gap between the wafer table **304** and the pad **326**, while the immersion fluid **312** below the optical assembly **16** moves between the wafer table **304** and the pad **326**. The immersion fluid containment system **324** thus maintains the immersion fluid **312** from the gap during wafer exchange. In this embodiment, the wafer table **304** (the wafer stage **306**) and the pad **326** are movable separately. Therefore, the wafer table **304** is movable freely while the immersion fluid **312** is maintained in the space between the pad **326** and the optical assembly **16**. In various embodiments of the invention, the control system **330** may be a separate control system or it can be integrated into the control system used to control the motors **322** for positioning the wafer stage **306** and wafer table **304**. Vertical position and/or tilt of at least one of the wafer table **304** and the pad **326** may be adjusted so that the wafer table surface is coplanar with the pad surface, before the wafer table is moved out from under the optical assembly **16**. The operation, in which the wafer table **304** is away from the optical assembly **16**, is not necessarily limited to a wafer exchange operation. For example, an alignment operation, a measurement operation or other operation may be executed while maintaining the immersion fluid **312** in the space between the pad **326** and the optical assembly **16**.

Referring to FIGS. **4**A and **4**B, two cross sections of an immersion lithography machine are shown. The lithography machine **400** includes an optical assembly **16** and a stage assembly **402** that includes a wafer table **404** and a wafer stage **406**. The wafer table **404** is configured to support a wafer **408** (or any other type of work piece) under the optical assembly **16**. An environmental system **26** (**410**), surrounding the optical assembly **16**, is used to supply and remove immersion fluid **412** from the gap between the wafer **408** and the lower most optical element of the optical assembly **16**. A work piece exchange system **416**, including a wafer loader **418** and an alignment tool **420**, is configured to remove the wafer **408** on the wafer table **404** and replace it with a second wafer. This is accomplished using the wafer loader **418** to remove the wafer **408** from the wafer table **404**. Subsequently, the second wafer (not shown) is placed onto the wafer chuck **418**, aligned using the alignment tool **420**, and then positioned under the optical assembly **16** as illustrated in the FIG. **4**A.

The immersion lithography machine **400** also includes an immersion fluid containment system **424** that is configured to maintain the immersion fluid **412** in the space below the optical assembly **16** while the wafer table **404** is away from under the optical assembly **16**. The immersion fluid containment system **424** includes a pad **426**, a first clamp **428** provided on the optical assembly **16** and a second clamp **430** provided on the wafer table **404**. When the immersion fluid **412** is between the optical assembly **16** and the wafer table **404** (or the wafer **408**), the pad **426** is held by the second clamp **430** in place on the wafer table **404**. When the wafer table **404** is away from the optical assembly **16**, for example during a wafer exchange operation, the pad **426** is detached from the wafer table **404** and held by the first clamp **428** to maintain the immersion fluid **412** between the optical assembly **16** and the pad **426**. The wafer table **404** has a flat upper surface that is coplanar with a surface of the wafer **408**. The pad **426** held on the wafer table **404** also has a flat upper surface that is coplanar with the upper surface of the wafer table **404** and the wafer surface. Therefore, the immersion pad **426** and wafer **408** can be moved under the optical assembly without the immersion fluid leaking. In various embodiments, the clamps **428** and **430** can be vacuum clamps, magnetic, electro-static, or mechanical.

As best illustrated in FIG. **4**A, the pad **426** is positioned on the wafer table **404** during exposure of the wafer **408**. The second clamp **430** is used to hold the pad **426** in place on the table **404** during the wafer exposure. During a wafer exchange as illustrated in FIG. **4**B, the wafer table **404** is moved in the direction of arrow **432** so that the pad **426** is positioned under the optical assembly **16** in place of the wafer **408**. When this occurs, the second clamp **430** holding the pad **426** to the wafer table **404** is released while first clamp **428** clamps the pad **426** to the optical assembly **16**. As a result, the immersion fluid **412** is maintained under the optical assembly while the wafer **408** is exchanged. After the new wafer has been aligned, the wafer table **404** is moved in the direction opposite arrow **432** so that the new wafer is positioned under the optical assembly. Prior to this motion, the first clamp **428** is released while the second clamp **430** again clamps the pad **426** to the wafer table **404**. In this embodiment, the wafer table **404** is freely movable while the pad **426** is clamped by the first clamp **428**.

In various embodiments, the operation, in which the pad **426** is clamped by the first clamp **428**, is not limited to only a wafer exchange operation. An alignment operation, a measurement operation, or any other operation can be executed while the immersion fluid **412** is maintained in the space between the optical assembly **16** and the pad **426** clamped by the first clamp **428**. Also, the clamp **428** can be provided on the frame **12** or other support member, and the clamp **430** can be provided on the wafer stage **406**. The pad **426** can be held on a movable member other than the stage assembly **402**.

FIGS. **5**A and **5**B are top down views of two different twin stage immersion lithography systems according to other embodiments of the present invention. For the basic structure and operation of the twin stage lithography systems, see U.S. Pat. No. 6,262,796 and U.S. Pat. No. 6,341,007. The disclosures of U.S. Pat. No. 6,262,796 and U.S. Pat. No. 6,341,007 are incorporated herein by reference in their entireties. In both embodiments, a pair of wafer stages WS1 and WS2 are shown. Motors **502** are used to move or position the two stages WS1 and WS2 in the horizontal direction (in the drawings), whereas motors **504** are used to move or position the stages WS1 and WS2 in the vertical direction (in the drawings). The motors **502** and **504** are used to alternatively position one stage under the optical assembly **16** while a wafer exchange and alignment is performed on the other stage. When the exposure of the wafer under the optical assembly **16** is complete, then the two stages are swapped and the above process is repeated. With either configuration, the various embodiments of the invention for maintaining immersion fluid in the gap under the optical assembly **16** as described and illustrated above with regard to FIGS. **2** through **4**, can be used with either twin stage arrangement. With regard the embodiment of FIG. **2** for example, each wafer stage SW1 and SW2 of either FIG. **5**A or **5**B can be modified to include a pad **222** and a support member **224**. With regard to the embodiment of FIG. **3**, a single pad **326**, motor **328**, and control system **330** could be used adjacent to the optical assembly **16**. The pad **326** is movable separately from the stages SW1 and SW2. During the time when stages SW1 and SW2 are to be swapped, the pad **326** is moved to under the optical assembly **16** to maintain the immersion fluid **312** below the optical assembly **16**. Finally with the embodiment of FIG. **4**, a detachable single pad can be used. During the time when stages SW1 and SW2 are to be swapped, the pad **426** is used to maintain the immersion fluid in the gap as illustrated in FIG. **4**B. On the other hand during exposure, the pad is clamped onto the wafer table on the wafer stage that is being exposed. In this manner, only a single pad is needed for the two stages WS1 and WS2. Alternatively, as described below, the second stage can also be used as the pad.

Referring to FIG. **6**A, a top down view of a twin stage lithography machine illustrating one embodiment of practicing the invention is shown. In this embodiment, the immersion lithography system **600** includes first stage **604** and second stage **606**. The two stages are moved in the X and Y directions by motors **602**. In this embodiment, the stages **604** and **606** themselves are used to contain the immersion fluid in the gap. For example as shown in the Figure, the first stage **604** is positioned under the optical assembly **16**. When it is time for the work piece to be exchanged, the motors **602** are used to position the second stage **606** with a second work piece adjacent to the first stage **604**. With the two stages positioned side-by-side, they substantially form a continuous surface. The motors **602** are then used to move the two stages in unison so that the second stage **604** is position under the optical assembly **16** and the first stage is no longer under the optical assembly **16**. Thus when the first work piece is moved away from the optical assembly **16**, the immersion fluid in the gap is maintained by the second stage **606**, which forms the substantially continuous surface with the first stage. In various alternative embodiments, the second stage **606** could also be a "pad" stage that contains a pad that is used to maintain the immersion liquid in the gap while a second work piece is being placed onto the first stage **604**. Similarly, the motor arrangement shown in either FIG. **5**A or **5**B could be used.

Referring to FIGS. **6**B-**6**E, a series of diagrams illustrating a work piece exchange according to one embodiment of the invention is illustrated. FIG. **6**B shows a wafer on stage **604** after exposure is completed. FIG. **6**C shows the second stage **606** in contact (or immediately adjacent) with the first stage **604** under the optical assembly **16**. FIG. **6**C shows a transfer taking place, i.e., the second stage **606** is positioned under the optical assembly **16**. Finally, in FIG. **6**E, the first stage **604** is moved away from the optical assembly **16**. As best illustrated in FIGS. **6**C and **6**D, the two stages **604** and **606** provide a continuous surface under the optical assembly **16** during a transfer, thus maintaining the immersion fluid in the gap. In the embodiment shown, the second stage **606** is a pad stage. This stage, however, could also be a work piece stage as noted above.

In the various embodiments described above, the pad can be made of a number of different materials, such as ceramic, metal, plastic. These materials may also be coated with Teflon according to other embodiments. The size of the pad also should be sufficient to cover the area occupied by the immersion fluid. In the various embodiments described above, the surface of the last optical element of the optical assembly **16** is constantly under immersion fluid environment, preventing the formation of a fluid mark (e.g. "a water mark").

Semiconductor wafers can be fabricated using the above described systems, by the process shown generally in FIG. **7**A. In step **701** the work piece's function and performance characteristics are designed. Next, in step **702**, a mask (reticle) having a pattern is designed according to the previous designing step, and in a parallel step **703** a wafer is made from a silicon material. The mask pattern designed in step **702** is exposed onto the wafer from step **703** in step **704** by a photolithography system described hereinabove in accordance with the invention. In step **705** the semiconductor work piece is assembled (including the dicing process, bonding process and packaging process); finally, the work piece is then inspected in step **706**.

FIG. **7**B illustrates a detailed flowchart example of the above-mentioned step **704** in the case of fabricating semiconductor work pieces. In FIG. **7**B, in step **711** (oxidation step), the wafer surface is oxidized. In step **712** (CVD step), an insulation film is formed on the wafer surface. In step **713** (electrode formation step), electrodes are formed on the wafer by vapor deposition. In step **714** (ion implantation step), ions are implanted in the wafer. The above mentioned steps **711**-**714** form the preprocessing steps for wafers during wafer processing, and selection is made at each step according to processing requirements.

At each stage of wafer processing, when the above-mentioned preprocessing steps have been completed, the following post-processing steps are implemented. During post-processing, first, in step **715** (photoresist formation step), photoresist is applied to a wafer. Next, in step **716** (exposure step), the above-mentioned exposure work piece is used to transfer the circuit pattern of a mask (reticle) to a wafer. Then in step **717** (developing step), the exposed wafer is developed, and in step **718** (etching step), parts other than residual photoresist (exposed material surface) are removed by etching. In step **719** (photoresist removal step), unnecessary photoresist remaining after etching is removed.

Multiple circuit patterns are formed by repetition of these preprocessing and post-processing steps.

While the particular lithography machines as shown and disclosed herein are fully capable of obtaining the objects and providing the advantages herein before stated, it is to be understood that they are merely illustrative embodiments of the invention, and that the invention is not limited to these embodiments.

What is claimed is:

1. An immersion exposure apparatus for exposing a substrate with an exposure beam via an optical element and immersion liquid, the apparatus comprising:

a table for mounting the substrate;

a member which is positionable under the optical element; and a holding member arranged to hold the member such that the member is located opposed to the optical element, wherein

each of the table and the member are configured to maintain the immersion liquid below the optical element when located opposed to the optical element,

the member is positionable to be away from a position below the optical element when the substrate, mounted on the table, is located opposed to the optical element, and

the table is movable to be away from below the optical element while the member is held opposed to the optical element.

2. The immersion exposure apparatus according to claim **1**, wherein the table and the member are movable for a transition from a first state to a second state, the first state being a state in which the immersion liquid is maintained in a space between the optical element and the table, the second state being a state in which the immersion liquid is maintained in a space between the optical element and the member, such that the immersion liquid is maintained below the optical element during the transition.

3. The immersion exposure apparatus according to claim **2**, wherein the table and the member are arranged to move in unison in the transition.

4. The immersion exposure apparatus according to claim **2**, wherein the apparatus is configured such that prior to the transition, a surface of the table and a surface of the member are coplanar.

5. The immersion exposure apparatus according to claim **1**, wherein the apparatus is configured such that the member is held opposed to the optical element while an operation is performed on a substrate mounted on the table.

6. The immersion exposure apparatus according to claim **5**, wherein the operation includes at least one of a substrate exchange operation, an alignment operation, and a measurement operation.

7. The immersion exposure apparatus according to claim **1**, wherein the member is releasably mountable to the table, and the apparatus is configured such that, while the table is located opposed to the optical element, the member is mounted to the table.

8. The immersion exposure apparatus according to claim **7**, wherein the apparatus is configured to hold the member released from the table by the holding member and to move the table relative to the member held opposed to the optical element so that the table is movable to be away from below the optical element.

9. The immersion exposure apparatus according to claim **7**, wherein the apparatus is configured such that, while an exposure operation of the substrate mounted on the table is performed, the member is mounted on the table.

10. The immersion exposure apparatus according to claim **1**, wherein the holding member is configured to releasably hold the member, and the apparatus is configured such that the member is released from the holding member when the table is located opposed to the optical element.

11. The immersion exposure apparatus according to claim **10**, wherein the apparatus is configured such that the member is released from the holding member when an exposure operation of the substrate mounted on the table is performed.

12. The immersion exposure apparatus according to claim **7**, wherein the table has a holding portion configured to releasably hold the member, and the apparatus is configured such that the member released from one of the holding member and the holding portion of the table is held by the other of the holding member and the holding portion.

13. The immersion exposure apparatus according to claim **12**, wherein the apparatus is configured such that the member held by the holding portion is positioned opposed to the optical element by moving the table, and then the member, once released from the holding portion, is held by the holding member.

14. The immersion exposure apparatus according to claim **12**, wherein the apparatus is configured such that the member is held by the holding portion when the table is located opposed to the optical element and the member is held by the holding member when the table is positioned away from below the optical element.

15. A device manufacturing method including a lithography process, wherein in the lithography process, a device pattern is transferred onto a substrate using the immersion exposure apparatus according to claim **1**.

16. An immersion exposure method of exposing a substrate with an exposure beam via an optical element and immersion liquid, the method comprising:

moving a table, which is capable of maintaining the immersion liquid below the optical element and on which the substrate is mounted, to locate the substrate to be exposed opposite to the optical element so that the immersion liquid is maintained in a space between the optical element and the substrate;

moving a member, which is capable of maintaining the immersion liquid below the optical element and which is locatable away from below the optical element when the substrate is opposite to the optical element, to be opposed to the optical element in place of the substrate;

holding the member below the optical element with a holding member so that the immersion liquid is maintained in a space between the optical element and the member; and

moving the table to be away from below the optical element while the member is held by the holding member opposed to the optical element.

17. The immersion exposure method according to claim **16**, wherein the table and the member are arranged to move for a transition from a first state to a second state, the first state being a state in which the immersion liquid is maintained in a space between the optical element and the table, the second state being a state in which the immersion liquid is maintained in a space between the optical element and the member, such that the immersion liquid is maintained below the optical element during the transition.

18. The immersion exposure method according to claim **17**, wherein the table and the member are arranged to move in unison in the transition.

19. The immersion exposure method according to claim **17**, wherein prior to the transition, a surface of the table and a surface of the member are coplanar.

20. The immersion exposure method according to claim **16**, wherein the member is held opposed to the optical element while an operation is performed on a substrate mounted on the table.

21. The immersion exposure method according to claim **20**, wherein the operation includes at least one of a substrate exchange operation, an alignment operation, and a measurement operation.

22. The immersion exposure method according to claim **16**, wherein the member is releasably mountable to the table, and while the table is located opposed to the optical element, the member is mounted to the table.

23. The immersion exposure method according to claim **22**, wherein the member released from the table is held by the holding member and the table is moved relative to the member held opposed to the optical element so that the table is movable to be away from below the optical element.

24. The immersion exposure method according to claim **22**, wherein, while an exposure operation of the substrate mounted on the table is performed, the member is mounted on the table.

25. The immersion exposure method according to claim **16**, wherein the holding member releasably holds the member, and the member is released from the holding member when the table is located opposed to the optical element.

26. The immersion exposure method according to claim **25**, wherein the member is released from the holding member when an exposure operation of the substrate mounted on the table is performed.

27. The immersion exposure method according to claim **22**, wherein the table has a holding portion which releasably holds the member, and the member released from one of the holding member and the holding portion of the table is held by the other of the holding member and the holding portion.

28. The immersion exposure method according to claim **27**, wherein the member held by the holding portion is positioned opposed to the optical element by moving the table, and then the member, once released from the holding portion, is held by the holding member.

29. The immersion exposure method according to claim **27**, wherein the member is held by the holding portion when the table is located opposed to the optical element and is held by the holding member when the table is positioned away from below the optical element.

30. A device manufacturing method including a lithography process, wherein in the lithography process, a device pattern is transferred onto a substrate using the immersion exposure method according to claim **16**.

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