METHOD AND APPARATUS FOR THE PHOTOLITHOGRAPHIC EXPOSURE OF EXCESS PHOTORESIST ON A SUBSTRATE

A system and method for exposing excess photoresist on the edges, sides and multiple surfaces of a photosensitized substrate. The substrate (1) is placed on a transparent chuck (2) and a mask (3) is placed on top of the substrate. The substrate is illuminated by lamps (11) to expose the unmasked areas on all sides of the substrate. A substrate transport system, masking system, mounting system, illumination system, loading system, alignment system, and machine control system are also disclosed.
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METHOD AND APPARATUS FOR THE PHOTOLITHOGRAPHIC
EXPOSURE OF EXCESS PHOTO RESIST ON A SUBSTRATE

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to the field of photolithographic techniques. The invention provides an improved photolithographic apparatus method for fabricating a multitude of electronic devices, including substrates used for thin film magnetic disk drive heads, multichip modules, silicon wafers used for active electronic devices, and other applications. More specifically, the present invention relates to a manufacturing method and apparatus wherein a photomask (hereafter called a mask) protects an area of a photosensitive substrate leaving the unwanted excess photoresist on the edges of the substrate exposed to illumination in the apparatus, thereby allowing the unwanted excess photoresist to be removed in a subsequent resist developing process step.

Description of the Related Art

Currently there are no machines specifically intended for this purpose of photolithographically exposing the excess photoresist on the edges of a substrate so that it may be removed. Various existing photomicrolithography machines may be used for the purpose, but they are not efficient. The three classes of machines are contact/proximity printers, scanners, and step-and-repeat printers. They are intended to be used to print high resolution images, a few micrometers or less in width, onto the top surface of the photosensitive substrate. They are relatively expensive machines. Due to the nature of their illumination system they do not
adequately expose the sides of a thick substrate, and do not expose the bottom surface at all. At the other end of the spectrum, some companies use cotton swabs and solvent to manually remove excess photoresist from the sides of substrates. This method is also not efficient. From reviewing the prior art it is apparent that an improved system and method for performing this operation on substrates is needed.

SUMMARY OF THE INVENTION

An improved system and method for processing substrates is provided by virtue of the present inventions. The inventions provide a means to expose excess photoresist on any or all sides of a substrate. A mask may be used to protect an area on one or more surfaces of the substrate. This process is repeated for numerous substrates quickly with a small, inexpensive, and reliable apparatus.

According to a preferred embodiment of the system, a substrate is placed on a transparent vacuum chuck to allow exposure of all sides and edges of the substrate. An opaque mask is placed in contact or close proximity and aligned over the area of the top surface of the substrate to be protected from exposure. The substrate with the mask and chuck are transported into an exposure chamber where all unmasked surfaces of the substrate are illuminated. A single axis stage system with attached chuck is employed to hold the substrate and move it into and out of the exposure chamber, perform substrate alignment, and move it into and out of a cassette for storage of multiple substrates.

Among photolithography tools, a unique object of this system is the use of fluorescent lamps as the light source. With the mask and chuck architecture used, neither a focused image or collimated light are required. Fluorescent lamps provide an efficient source of actinic light from their large extended surfaces and have a long
useful life.

An alignment system locates the substrate on the chuck such that the mask is aligned over the area of the top surface of the substrate to be protected from exposure. The alignment system also locates the substrate on the chuck such that the substrate is located on a centerline of the substrate cassette to aid in returning the substrate successfully to the cassette, especially a square substrate.

A substrate cassette elevator is included to allow for automatic exchange of the substrates to and from the substrate chuck and a substrate cassette that holds multiple substrates. The stage system transports the substrate from a substrate storage cassette located on the front of the machine, to the alignment system, then into the exposure chamber. After exposure the substrate is returned to an unoccupied slot in the cassette.

A further understanding of the nature and advantages of the invention herein may be realized by reference to the subsequent text and attached drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other objects, features and advantages of the present invention will become apparent from the following detailed description of the accompanying drawings, in which:

Fig. 1 is a right side view with the cover removed showing most of the internal parts of an embodiment of the invention;

Fig. 2 is an isometric view of the embodiment of Fig. 1 showing the front panel user interface, the exterior panels, and some internal components;

Fig. 3 is a detailed view of the stage assembly, including an isometric view, a side view with the mask closed, and a side view with the mask open;

Fig. 4 illustrates features of the substrate chuck including top, side and end views, and an exploded
isometric view;

Fig. 5 illustrates features of the substrate mask;

Fig. 6 illustrates the substrate alignment system;

Fig. 7 is a top view of the embodiment of Fig. 1 with a front section and a middle section of the top cover cut away showing the top lamps and the cassette elevator system;

Fig. 8 is a right side view of the embodiment of Fig. 1 with the cover removed showing most of the internal parts including a substrate on the stage in the exposure chamber.

**DESCRIPTION OF THE PREFERRED EMBODIMENTS**

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I. Overall Machine Description

Figs. 1 and 2 are overall drawings of a photolithography machine. The machine includes a user interface system mounted on a front panel 5 of an enclosure that provides the user with all necessary system controls and status information. Fig. 1 shows the machine without enclosure panels to expose internal parts. On the front of the machine an elevator system for a substrate cassette 8 is mounted which provides a vertical motion allowing access to substrates that facilitates automatic processing of many substrates.

Fig. 1 also shows a stage system comprising a stage slider rail 19 and stage slider 20 on which is mounted a
chuck pedestal 23, a substrate chuck 2, and substrate mask 3. The stage is constrained to move in one axis from the front of the machine to an exposure chamber toward the rear of the machine. The stage aids in accessing the substrates 1 in the substrate cassette 8 for automatic operation and provides the motion required to deliver the substrate to and from the exposure chamber after an alignment operation is performed by an alignment system.

Fig. 6 shows the alignment system comprising three assemblies 40, 41, 42. The alignment system positions the substrate on the chuck producing two effects. The substrate is positioned onto a centerline of the substrate cassette 8 to aid in the successful return of the substrate into the cassette. Also the edges of the substrate are positioned relative to the substrate chuck 2 and substrate mask 3 that are mounted on the stage such that the mask will properly cover the area on the top surface of the substrate 1 that is to be protected from exposure.

Figs. 1 and 2 also show that the exposure chamber is a box within the machine with reflective inside surfaces on the exposure chamber walls 7. Inside the chamber is mounted light source lamps 11 that emit ultraviolet light of the proper spectrum to expose photoresist on the substrate 1. A plurality of large lamps 11 is used to insure exposure of all exposed surfaces on the substrate in a period of time. The stage delivers the mask 3 and the substrate 1 on the chuck to and from the exposure chamber. The exposure dose is controlled by a system controller 12 and set by the user on the user interface on the front panel 5.

A machine electronics system that includes system software in a system controller 12, controls the operation of the functions of the machine to perform processes as described in the operation section.
Due to the overall architecture of the machine, only access to the front of the machine is required for operation and normal maintenance. This feature yields a machine with a small projected floor area and the ability to locate systems directly next to one another or stack them on a rack. The combination of elements comprising the machine produces a system with a total size of less than 20 inches high by 20 inches wide by 36 inches deep, a weight of less than 100 pounds, and compatibility with substrates up to 6 inches square and 0.20 inches thick.

II. Stage System

Figs. 1, 3, 4, 5 illustrate the stage system. The stage system allows for holding, masking and aligning the substrate and its transportation between the exposure chamber and a storage cassette. The stage system is comprised of a linear stage slider 20 on a stage slider rail 19 driven by a stage stepper motor 21 via a stage toothed belt and stage pulleys, a chuck pedestal 23, a substrate vacuum chuck 2, a substrate mask 3, and various pneumatic components that operate the mask motion and vacuum and sensing to the mask and chuck.

Another element of the stage assembly is a pair of photo interrupter sensing devices 25, 22 located adjacent to the stage slider rail 19 and fixed to a machine base 28, shown in Fig. 1. A thin rigid stage flag 26 is attached to the stage slider 20 such that it interrupts a front stage sensor 22 in the stage travel range in which the mask must be in the up position to avoid damage and interrupts a rear stage sensor 25 in the stage travel range in which the mask must be in the down position to avoid damage.

The stage slider 20 is a precision ball bearing type linear slider on a long rigid stage slider rail 19. The stage slider confines the stage to move along the horizontal axis only from the front to the rear of the machine. The stage slider rail is rigidly fixed to the
machine base 28 in a precisely horizontal orientation. The stage slider is drive by a rotary stage stepper motor 21 via a toothed belt 18 and pulleys 17 that provide for a gear ratio and tolerance to misalignment. The stepper motor is rigidly mounted to the machine base 28. The stepper motor is driven by a stage electronic motor driver 27 for smooth motion, that is controlled by the system controller 12. Another element of the stage are two micro switches that sense the far front and the far rear limits of the stage travel.

The chuck pedestal 23 in Figs. 1 and 3 is a flange that is mounted to the stage slider 20. The chuck pedestal is a mount for the substrate chuck 2 and the substrate mask 3. It supports the chuck and mask above the stage slider and an exposure chamber floor 30. This arrangement separates the substrate from the relatively dirty environment around the stage slider by the exposure chamber floor.

The substrate vacuum chuck 2, shown in Figs. 3 and 4, is the device that holds the substrate 1 during its transport, alignment and exposure. The chuck is rigidly mounted in a cantilever fashion to the chuck pedestal 23 such that it moves with the stage. The chuck is made of quartz to produce an element that is transparent to ultraviolet light to allow exposure of all surfaces of the substrate without shadows cast by the chuck. The quartz could have an anti-reflection coating to further increase its transparency. The chuck is long enough to support the substrate substantially over its center of gravity to insure stability, and far enough from the pedestal to prevent the pedestal from casting a shadow on the substrate while they are in the exposure chamber. The chuck width is less than the width of the substrate but wide enough to insure stability of the substrate. The chuck 2, shown in Fig. 4, has a raised area around the vacuum pads where the center of the substrate is
supported. This configuration eliminates contact between the chuck and the edge of the substrate thereby reducing any shadow that might be cast by the optically discontinuous edge of the chuck onto the edge of the substrate.

The raised area of the chuck has a top surface that is flat and smooth and at least one shallow indentation. The shallow indentation is polished to become transparent and fed with vacuum forming a transparent vacuum cavity to hold a substrate called a chuck vacuum pad 31. The vacuum to the chuck vacuum pad is supplied through a small hole in the bottom of the chuck vacuum pad into a transparent pneumatic plenum called a chuck plenum 32 formed in the otherwise solid transparent quartz chuck. The chuck plenum leads to a pneumatic coupling at the pedestal that is plumbed via flexible hose to solenoid valves and then to the vacuum source.

The quartz chuck is manufactured by grinding the vacuum pads into the top surface of a quartz plate 37. On the reverse side the plenum channels are ground. The vacuum pads and plenum are connected by drilling through the bottom of the vacuum pads through to the plenum. All ground surfaces are polished to retain transparency. A second plate of quartz 38 is then glued with optical cement or thermally fused onto the reverse side of the first quartz plate to complete the plenum and the quartz substrate vacuum chuck 2.

The substrate mask 3, shown in Figs. 1, 3 and 5, is the device that masks the area of the top surface of the substrate 1 that is not supposed to be exposed. The mask is mounted on a mask flexure 33 that is rigidly mounted to a cantilevered quartz mask beam 34 that is rigidly mounted on a rotary bearing on the chuck pedestal 23 such that it moves with the stage. The mask is made of an opaque, stable, plastic that is tolerant to ultraviolet light. The mask is as thin as practical while
maintaining a stable flat surface to contact the substrate. The top perimeter of the mask is beveled to minimize any shadow cast by any exposing light aimed at the top surface of the substrate immediately adjacent to the perimeter of the mask. The bottom surface of the mask that contacts the substrate is concave to create a mask vacuum pad 35. Only a narrow perimeter strip of the bottom surface of the mask contacts the substrate. The vacuum to the mask vacuum pad 35 is supplied through a small hole through a gas coupling on the top of the mask and via flexible hose to solenoid valves and then to the vacuum source.

The mask flexure 33 provides mechanical latitude to parallelism and thickness tolerances of the mask 3, chuck 2 and the substrate 1. A coupling between the mask flexure and the mask is rigid but allows for quick replacement of the mask for cleaning without disturbing the relative alignment of the mask to the flexure while coupled.

The purpose of the quartz mask beam 34 is to support the mask 3 on a cantilever mount to the pedestal 23 without blocking light required to expose all surfaces of the substrate 1. The quartz mask beam has an anti-reflection coating to further increase its transparency. The mask beam 34 is mounted on a rotary bearing on the chuck pedestal 23 with its axis of rotation coplanar with the top surface of the substrate such that when the mask is lowered onto the substrate by rotating the bearing the mask motion is purely normal to the surface of the substrate thereby producing no abrasion upon contact with the substrate. The mask motion is executed by a mask actuator 36 piston.

An alternate mask mount system would not allow a mask to physically contact the top surface of the substrate. The mask would be rigidly mounted to a cantilevered quartz mask beam 34 that is rigidly mounted
on a rotary bearing on the chuck pedestal 23 as before. A positioning pin 4 would be added attached to the mask mount that would limit the rotation of the mask mount to set a proximity limit between the mask mount and the substrate mount.

Another alternate masking system would retain the flexure mount system for tolerance flexibility but would include a mask that incorporates air bearings in the surface that faces the substrate in place of the mask vacuum pad 35. The air bearings would allow the mask to closely approach the substrate but prevent contact with it.

III. Alignment System

Fig. 6 illustrates the alignment system. The alignment system positions the substrate 1 on the chuck 2 producing two effects. The substrate is positioned onto the centerline of the cassette 8 to aid in the successful return of the substrate into the cassette particularly when a square substrate is used. Also the edges of the substrate are positioned relative to the chuck and mask that are mounted on the stage such that the mask 3 will properly cover the area on the top surface of the substrate that is to be protected from exposure.

The alignment system is composed of three separate actuator assemblies. A right side alignment assembly 40 contains two small rotary bearings 43 that will be moved to a fixed position and contact the right side of the substrate to set the alignment position in two axes. Rotary bearings are used for substrate contact points to allow rolling rather than scraping of the contact points on the substrate. This device is mounted on a rotary bearing constrained to the horizontal plane and fixed to the machine base plate 28. It is actuated by a pneumatic piston that rotates the two bearings into position adjacent to the chuck 2 or out of the way to the side.
A left side alignment assembly 41 contains one small rotary bearing 44 that will contact the left side of the substrate and push the substrate into contact with the right side alignment assembly 40 thereby locating the substrate 1 in the horizontal axes. This device is mounted on a rotary or a linear bearing constrained to the horizontal plane and fixed to the machine base plate 28. It is actuated by a pneumatic piston that moves the bearing into position adjacent to the chuck 2 or out of the way to the side. The two side aligning assemblies 40,41 are actuated and de-actuated simultaneously to perform substrate alignment.

To accomplish substrate alignment in the front to rear axis a front side alignment assembly 42 is used. It is located in front of the substrate when the substrate 1 in on the chuck 2 in position to be aligned. It is comprised of a forth small rotary bearing 45 that is mounted to a third pneumatic actuator that moves it into place for substrate alignment or out of the way when it is not needed. To align the substrate in the front to rear axis the stage would move forward to let the substrate contact the forth bearing and slide into position.

An alternate alignment system that would be applicable to round substrates would also be comprised of three alignment assemblies. Two assemblies would be mirror images of each other and would be disposed on opposite sides of the substrate like the right and left side alignment assemblies. Each would contain one small rotary bearing that would be moved to a fixed position adjacent to the substrate to set the alignment position. These mechanisms would be actuated by pneumatic pistons that move the two bearings into position adjacent to the chuck or out of the way to the side. A front side alignment assembly would be located in front of the substrate when the substrate is on the chuck in position
to be aligned. It is comprised of a third small rotary bearing that is mounted to a third pneumatic actuator that moves it into place for substrate alignment or out of the way when it is not needed. To affect alignment the stage would move forward to let the substrate contact the third bearing and slide into position. For lithography on round substrates with a preferred orientation indicated by a notch or flat like silicon wafers for semiconductor manufacture, a flat finding system would be required.

IV. Exposure Chamber

Figs. 1 and 2 illustrate the exposure chamber section of the machine. The exposure chamber contains an array of long fluorescent ultraviolet lamps 11. The type of lamp used produces most of its output power in the spectrum from 350 nanometers wavelength to 440 nanometers which is optimal actinic light for the photoresist chemistries that are currently dominant in the industry. They also produce a relatively insignificant amount of dangerous deep ultraviolet radiation compared to Mercury arc lamps, and produce a relatively insignificant amount of infrared radiation compared to any other common ultraviolet light source. The fluorescent lamps emit uncollimated and unfocused light over a large area. The lamps 11 are arrayed lamps above and below the substrate 1 when the substrate is on the chuck 2 in the exposure chamber. The lamps are spaced to substantially cover the top and bottom surfaces and overhang all edges of the substrate so that a significant amount of direct radiation from the lamps impinges on all surfaces and edges of the substrate simultaneously.

To decrease the required exposure time alternate lamps and arrangements may be used. Special lamps with internal radiation concentrators can be used to direct more of the produced light directly toward the substrate. Another useful technique would be pulsing the lamps to
high power levels during exposure then reducing power to an idle level. Lamp tubes with various shapes may be used to cover the required area: straight, "U" shaped, or serpentine.

The exposure chamber is bounded by reflective aluminum exposure chamber walls 7 that serve to integrate the light in the chamber and reflect it toward all surfaces of the substrate. The front wall has a "T" shaped exposure chamber front door 61 in it to allow the stage with a substrate to pass through the wall while limiting the amount of escaping light. The exposure chamber floor 30 has a slot in it through which the stage pedestal protrudes. The lamps in the chamber are oriented with their major axis parallel to the plane of the substrate and the axis of motion of the stage to allow the stage to move the substrate between the lamps. Since the light production efficiency of fluorescent lamps is strongly temperature dependent, a thermostatically controlled fan is used to control the temperature of the lamps.

Lamp power detectors 62 adjacent to each lamp are used to detect the power output of each lamp 11. The signals are fed to the system controller 12 to report to the user interface when a lamp is bad. The signals are also used to compensate the substrate exposure time for any decrease in lamp power due to aging or facility’s source voltage fluctuations.

V. Cassette Elevator

Figs. 1 and 7 illustrate a cassette elevator system. The system acts as a substrate loader to allow for the automatic transfer of substrates on to and off of the stage. Although the lithography operation can be executed manually by transferring the substrates by hand this function is necessary to decrease labor and improve the substrate processing rate. The elevator system is comprised of a horizontally mounted elevator platform 50,
a vertical lead screw 53 and elevator drive motor 51 attached to one side of the elevator platform, and a vertically mounted elevator slider 52 attached to the other side of the elevator platform 50. The vertical lead screw 53 drive mechanism could be replaced with an alternate drive means such as a toothed belt and pulley. To increase the holding force of a belt and pulley mechanism a gear train could be employed.

Another element of the cassette elevator system is an emitter and photodetector pair configured as a substrate photo interrupter pair 54 located adjacent to the elevator platform 50 but fixed to the machine base. They are situated such that the infrared light beam passes through the openings in the sides of a standard substrate cassette 8 and is interrupted by an opaque substrate 1 if one is present in the cassette slot that is currently aligned to the photo interrupter pair.

The elevator platform 50 is composed of a plate with alignment pins to engage the features of a standard substrate cassette 8. Another element of the cassette elevator platform are two micro switches that sense a properly mounted cassette. The elevator platform is coupled to the vertical elevator slider and vertical lead screw each via rigid flanges.

The elevator slider 52 is a precision ball bearing type slider on a rigid elevator slider rail 59. The slider confines the cassette elevator platform 50 to move along the vertical axis only. The elevator slider rail 59 is rigidly fixed to the base of the machine in a precisely vertical orientation.

The elevator lead screw 53 is attached via rotary bearings 57 to the machine base 28 in a precisely vertical orientation. The screw transfers vertical motion to the elevator platform 50 via an antibacklash nut mounted in a flange attached to the platform. An elevator drive motor 51 drives the screw in a rotary
fashion. The two are coupled together by a toothed drive belt and pulleys that provide for a gear ratio and tolerance to misalignment. The elevator drive motor 51 is rigidly mounted to a flange to the machine base 28. The elevator drive motor is driven by an elevator electronic motor driver 60 for smooth motion, that is controlled by the system controller 12. Another element of the associated with the elevator drive system are two micro switches that sense the top and bottom limits of the elevator travel.

Another element of the cassette elevator system is the portion of a front wall of the machine that is predominately solid except that it has a slot in it just large enough to allow a substrate on the substrate chuck to pass through it from the cassette to the rear sections of the machine and return. This front aperture 58, shown in Figs. 1 and 2, protects the inside mechanisms of the machine from damage from external sources, and further isolates the photosensitive substrates in the cassette from stray ultraviolet light from the exposure chamber.

VI. **Electronics**

The machine electronics system consists of the system controller 12, a plurality of sensors, a plurality of drivers for pneumatic actuators, the two stepper motors 21,51 and their drivers 27,60, the illumination light source lamps 11, a power supply for the electronics, and a thermostatically controlled fan 6 for cooling, as shown in Fig. 1.

The system controller 12 is based on a programmable motor controller. It has a serial data port used for programming and an associated read-only memory to store the program. To expand its input and output addressing capacity some digital decoding and encoding logic is added. Digital inputs from sensors are encoded onto a single bit input to the controller. Outputs are decoded from the controller to control user interface indicators.
and control power drivers that in turn drive pneumatic solenoid valves to control the mechanical actions in the machine. The controller is primarily a stepper motor controller. An output data bit is used to direct the motor controller signals to one of the two stepper motors. One motor 21 drives the stage with the attached chuck and mask. The other stepper motor 51 drives the cassette elevator. An exposure timer is an analog timer programmable from a digital potentiometer on the user interface on the front panel 5. The time setting is altered to compensate for lamp power variations over time sensed by the light sensors associated with each lamp 11.

VII. Software

The system software is written in a special language of the system controller 12. The software is stored in a read-only memory. The software contains a machine initialization routine that is executed upon application of system power. The software contains modules to deal systematically with casualty conditions to prevent damage to either the machine or the substrates and indicate status via the user interface on the front panel 5. The software also contains a main process operations code that controls the machine through a process sequence described in an operation section of this document.

VIII. User Interface

The user interface system is mounted on the front panel 5 of the machine for best human interaction as illustrated in Fig. 2. As described previously, this system interfaces with the system controller 12. The user interface provides a system power switch, an hour meter to monitor the total life of the machine, the digital potentiometer used to set the exposure dose, a start button used to initiate, pause and resume the process. Also included are a plurality of machine and process status indicator lights. These include indicators of the following situations: processing,
halt, assist, no substrate, no cassette, no air, weak
lamp, bad lamp, substrate number, mask stuck up, mask
stuck down, alignment mechanism stuck. As an
alternative, a more expensive but more flexible user
interface may be used such as a keyboard and video
monitor.

IX. Operation

During normal operation a sequence of events for the
preferred embodiment would proceed as follows. An
initial configuration would be with the stage at an
alignment position, mask up, cassette elevator in a
lowest position, and a substrate counter set to zero.

First a cassette 8 of substrates 1 would be placed
on the cassette elevator platform 50. When the start
button is pushed "processing" light would be turned on.
The cassette elevator would be moved up until the first
substrate is slightly above the plane of the top surface
of the chuck 2. The substrate photointerrupter pair 54
will detect the presence of the substrate in the cassette
at a correct position. If the substrate is not sensed a
"no substrate" light would be turned on. After a five
second delay the cassette elevator would move up to a
next position and processing would continue.

If the substrate is sensed at a correct position in
the cassette the stage would move forward to position the
chuck in the cassette under the center of the substrate.
The cassette elevator would move down slightly to let the
substrate rest on the chuck. Then the chuck vacuum would
be turned on to hold the substrate on the chuck and the
chuck vacuum would be sensed to verify the presence of
the substrate. If the substrate is not sensed the system
controller 12 would turn on user interface lights
indicating "no substrate", "assist", and "pause", check
for system air source pressure then wait for vacuum to be
sensed.

When the substrate 1 is successfully transferred to
the chuck 2 the stage would move toward the rear of the machine to a prealign position. Then the chuck vacuum strength would be reduced to allow for sliding of the substrate on the chuck.

To accomplish substrate alignment the alignment mechanisms 40,41,42 would be moved into place, clamping the substrate between three bearings to position the substrate parallel to the front to rear centerline of the machine, and positioning a forth bearing in front of the substrate. To align the substrate along the front to rear axis the stage would move forward to let the substrate contact the forth bearing and slide into position.

After alignment the substrate mask 3 would close onto the top of the substrate 1, full vacuum on the mask and chuck would be engaged, then the alignment assemblies would be retracted.

To expose the substrate on the stage would move to the rear of the machine between the lamps 11 in the exposure chamber for the time preset by the user. When the exposure time has elapsed the stage would move back to the prealign position, the mask vacuum would be released and the mask 3 raised.

Then the exposed substrate would be returned to the cassette by moving the stage forward into an empty slot in the cassette. Chuck vacuum would be released and the cassette elevator raised slightly to transfer the substrate from the chuck to the cassette.

To continue the process with the next substrate in the cassette the stage would move to out of the cassette to the alignment position. The cassette elevator platform 50 would move up to access a next substrate slot in the cassette 8 and the substrate photointerrupter pair 54 would look for the presence of the next substrate 1.

XI. Conclusions

The system has many and various desirable features,
and allows for the ready incorporation of additional features. Among the most desirable are the following features: the machine is substantially smaller than other tools that could be used for this process, it is close to optimally simple for the purpose intended, the light sources and mechanisms chosen provide an unprecedented long operational lifetime, it produces a low facility’s impact, and allows for thick square substrates. The above system provides a substantially improved system and method for the exposure of a photosensitized substrate.

The above description is illustrative and not restrictive. Many variations of the invention will become apparent to those of skill in the art upon review of this disclosure. Merely by way of example different materials of construction may be utilized, other light sources may be utilized, a substrate flat finder may be added for use with round substrates, and numerous status sensors and user interface elements may be added. This invention may also be incorporated for the purpose of edge bead exposure as a subsystem into a conventional photomicrolithography tool or into a wafer processing track system. The scope of the invention should therefore be determined not with reference to the above description, but instead should be determined with reference to the appended claims along with their full scope of equivalents.
CLAIMS

What is claimed is:

(ILLUMINATION)

1. A method for illuminating a surface of a substrate in a photolithographic system comprising the step of illuminating the substrate using a fluorescent lamp as an actinic light source.

2. A method for illuminating a surface of a substrate in a photolithographic system comprising the step of illuminating the substrate using an uncollimated and unfocused actinic light source.

3. A photolithographic system comprising a fluorescent lamp used as an actinic light source.

4. A method for exposing a surface of a substrate in a photolithographic system comprising the step of simultaneously exposing multiple surfaces of the substrate.

5. A photolithographic system for simultaneously exposing multiple surfaces of the substrate.

(SYSTEM)

6. A method of processing a substrate comprising the steps of:
   moving a substrate mount into the cassette between the substrates below a particular substrate;
   moving the cassette downward to let the particular substrate come to rest on the substrate mount;
   moving the substrate mount with the particular substrate resting thereon out of the cassette to a predetermined position;
   affecting a process on the particular substrate resting on the substrate mount; and
returning the particular substrate back into an empty slot in the cassette by reversing the first three steps above.

7. A photolithographic system for processing a substrate comprising:
   a substrate mount; and
   a means for moving a substrate resting on the substrate mount to a position for affecting a process thereon.

8. A photolithographic system for processing a substrate according to claim 7 further comprising:
   a means for automatically transferring a substrate from a substrate cassette to the substrate mount; and
   a means for automatically transferring a substrate from the substrate mount back into an empty slot in the cassette.

9. A photolithographic system for processing a substrate according to claim 7 further comprising a means for aligning the substrate on the substrate mount to a predetermined position.

10. A photolithographic system for processing a substrate according to claim 9 wherein the substrate on the substrate mount is aligned to a position relative to the cassette position.

11. A method for exposing the excess photoresist on the perimeter of a substrate in a photolithographic system comprising the steps of:
   covering a surface of a substrate with a mask
   exposing only the excess photoresist on the substrate; and
exposing the excess photoresist on the substrate to actinic illumination.

12. A method for exposing the excess photoresist on the perimeter of a substrate in a photolithographic system according to claim 11 wherein the actinic illumination is provided by a fluorescent lamp.

13. A method for exposing the excess photoresist on the perimeter of a substrate in a photolithographic system according to claim 12 further comprising the step of aligning the substrate to a predetermined position relative to the mask.

14. A method for exposing the excess photoresist on the perimeter of a substrate in a photolithographic system according to claim 13 further comprising the steps of:

automatically transferring a substrate from a substrate cassette to a substrate mount; and
automatically transferring the substrate from the substrate mount back into an empty slot in the cassette.

15. A method according to claim 6 wherein the third step further comprises the step of moving said substrate mount with said particular substrate resting thereon, to a substrate alignment position.

16. A method according to claim 6 wherein the third step further comprises the step of aligning the particular substrate using an alignment mechanism to a position relative to the cassette position.

17. A system having a mask used for illuminating photoresist on a substrate comprising:

a source of uncollimated and unfocused illumination;
and
means for moving the mask and the substrate simultaneously to and from the illumination.

18. A system as recited in claim 17 wherein said illumination source comprises a means for illuminating multiple surfaces of said substrate simultaneously.

19. A photolithographic system for exposing a substrate comprising a means of positioning one photolithographic system above another and maintain accessibility to all systems by a human standing on the floor.

20. A method for installing a photolithographic systems for exposing a substrate comprising the step of positioning one photolithographic system above another and maintain accessibility to all systems by a human standing on the floor.

21. A photolithographic system for exposing a substrate with an architecture comprising:
   a means with which to load a substrate onto a substrate mount and return the substrate from the substrate mount (thereof referred to as a "substrate loader");
   a substrate alignment means adjacent to the substrate loader;
   a substrate exposure means adjacent to the substrate alignment means and collinear and on the opposite side of the substrate alignment means from the substrate loader. (ALIGNMENT)

22. A method for aligning a rectangular substrate on a substrate mount comprising the steps of:
   moving two contact points to a preset and fixed position adjacent to a first edge of the substrate;
moving a third contact point to a second edge of the substrate that is opposite the first edge of the substrate;
pushing the substrate with the third contact point against the two contact points to locate the substrate on the substrate mount in relation to a first translational axis and a rotational axis both coplanar with the substrate;
moving a forth contact point to a preset and fixed position adjacent to a third edge of the substrate orthogonal to the first and second edges;
pushing the substrate against the forth contact point to position the substrate on the substrate mount in relation to a second translational axis orthogonal to the first translational axis and parallel to the plane of the substrate.

23. A system for aligning a rectangular substrate on a substrate mount comprising:
a means for moving two contact points to a preset and fixed position adjacent to a first edge of the substrate;
a means for moving a third contact point to a second edge of the substrate that is opposite the first edge of the substrate;
a means for pushing the substrate with the third contact point against the two contact points to locate the substrate on the substrate mount in relation to a first translational axis and a rotational axis both coplanar with the substrate;
a means for moving a forth contact point to a preset and fixed position adjacent to a third edge of the substrate orthogonal to the first and second edges; and
a means for pushing the substrate against the forth contact point to position the substrate on the substrate mount in relation to a second translational axis
orthogonal to the first translational axis and parallel to the plane of the substrate.

(SUBSTRATE MOUNT)

24. A substrate mount for holding a substrate in a photolithographic system comprising a transparent chuck.

25. A substrate mount as recited in claim 24 wherein said transparent chuck comprises a transparent vacuum cavity.

26. A substrate mount as recited in claim 24 wherein said transparent chuck comprises a transparent pneumatic plenum.

27. A substrate mount as recited in claim 24 wherein said transparent chuck comprises a raised area on which the substrate is supported.

28. A substrate mount as recited in claim 24 wherein said transparent chuck comprises:
   a first transparent plate with orifices or cavities formed in it;
   a second transparent plate with or without orifices or cavities formed in it; and
   a means for joining the first transparent plate and second transparent plate together.

29. A substrate mount as recited in claim 28 wherein said transparent chuck comprises:
   a first transparent plate with orifices or cavities formed in it;
   a second transparent plate with or without orifices or cavities formed in it; and
   a means for joining the first transparent plate and second transparent plate together to form a pneumatic or vacuum plenum.
30. A method for manufacturing a transparent substrate mount comprising the steps of:
   forming orifices or cavities in a first transparent plate;
   forming orifices or cavities in a second transparent plate; and
   joining the first transparent plate and second transparent plate together to form a pneumatic or vacuum plenum.

31. A method for manufacturing a transparent substrate mount comprising the steps of:
   forming orifices or cavities in a first transparent plate;
   a second transparent plate; and
   joining the first transparent plate and second transparent plate together to form a pneumatic or vacuum plenum.

(MASK MOUNT)

32. A mask mount used to support a mask in a photolithographic system for exposing a substrate comprising:
   a transparent beam; and
   a mask mount attachment means to attach the mask to the transparent beam.

33. A method for positioning a mask on a substrate in a photolithographic system comprising the step of rotating the mask about a pivot line.

34. A mask mount used to support a mask in a photolithographic system for exposing a substrate comprising a mask flexure.
35. A combined mask mount and substrate mount in a photolithographic system for exposing a substrate comprising:
   a substrate mount attached to a pedestal;
   a mask mount attached to the pedestal parallel to the substrate mount; and
   an attachment means linking the mask mount to the pedestal allowing the mask mount be moved relative to the substrate mount.

36. A combined mask mount and substrate mount as recited in claim 35 further comprising a means for setting a proximity limit between a mask and a substrate.

(MASK)

37. A mask used in a photolithographic system for exposing a substrate comprising a plate of opaque material having a top surface with beveled edges to allow light to reach the exposed areas of the substrate from an incident angle of greater than ninety degrees from the surface of the substrate.

38. A mask used in a photolithographic system for exposing a substrate comprising a concavity on the surface that faces a substrate.

39. A mask used in a photolithographic system for exposing a substrate comprising a downward protruding perimeter rim member on the surface that faces a substrate.

40. A mask used in a photolithographic system for exposing a substrate comprising a means to provide a pressurized gas into the mask to separate the mask from the substrate.
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC(S) : G03B 9/00, 9/08; G03F 9/00; G03C 1/492, 1/76
US CL : 354/228, 230; 430/4, 5, 270, 328
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
U.S. : 354/228, 230; 430/4, 5, 270, 328, 329, 331, 644; 427/444

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
APS: photolithography, fluorescent, multiple substrates, wafers, elevator, substrate mount, mask mount, substrate storage

C. DOCUMENTS CONSIDERED TO BE RELEVANT

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
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<tbody>
<tr>
<td>Y</td>
<td>US, A, 5,114,834 (NACHSHON) 19 MAY 1992. See the Abstract.</td>
<td>1-4, 6, 11-16</td>
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<tr>
<td>Y</td>
<td>US, A, 4,256,829 (DANIEL) 17 MARCH 1981. See the Abstract and column 1, lines 18-51; column 4, lines 8-22; column 10, line 51, to column 11, line 54.</td>
<td>1, 2, 4, 6, 11, 12, 13, 15, 16, 35, 36</td>
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<tr>
<td>Y</td>
<td>US, A, 4,969,169 (FORSYTH ET AL) 06 NOVEMBER 1990. See the Abstract and column 5, line 35, to column 9, line 18.</td>
<td>4, 6, 13-16, 35, 36</td>
</tr>
<tr>
<td>Y</td>
<td>US, A, 4,735,877 (KATO ET AL) 05 APRIL 1988. See column 3, line 57, to column 4, line 19.</td>
<td>1-4, 12</td>
</tr>
</tbody>
</table>

[X] Further documents are listed in the continuation of Box C.  [ ] See patent family annex.

Date of the actual completion of the international search
26 January 1994

Date of mailing of the international search report
FEB 24 1994

Name and mailing address of the ISA/US Commissioner of Patents and Trademarks
Box PCT
Washington, D.C. 20231

Authorized officer
SUSAN BERNAN

Authorized officer
Telephone No. (703) 308-2351

Facsimile No. NOT APPLICABLE

Form PCT/ISA/210 (second sheet)(July 1992)
<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y</td>
<td>US, A, 4,935,334 (BOETTIGER ET AL) 19 JUNE 1990. See the Abstract and Figures 1-7. See column 3, line 36, to column 4, line 4; and column 4, line 61, to column 5, line 14.</td>
<td>4, 6, 11-16, 35, 36</td>
</tr>
</tbody>
</table>
INTERNATIONAL SEARCH REPORT

Box I  Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.: because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.: because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.: because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box II  Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

Please See Extra Sheet.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ✗ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

   1-4, 6, 11-16, 35 and 36

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest: ☐ The additional search fees were accompanied by the applicant’s protest.

   ✗ No protest accompanied the payment of additional search fees.

Form PCT/ISA/210 (continuation of first sheet(1))(July 1992)
BOX II. OBSERVATIONS WHERE UNITY OF INVENTION WAS LACKING
This ISA found multiple inventions as follows:

I. Claims 1-3, drawn to a method for illuminating a surface of a substrate in a photolithographic system and to a photolithographic system comprising a fluorescent lamp, classified in Class 354, subclass 228.

II. Claim 4, drawn to a method of simultaneously exposing multiple surfaces of a substrate, classified in Class 430, subclass 4.

III. Claim 5, drawn to a photolithographic system for simultaneously exposing multiple surfaces of a substrate, classified in Class 354, subclass 228+.

IV. Claims 6, 15 and 16, drawn to a method of processing a substrate using a substrate mount and a cassette, classified in Class 430, subclass 4.

V. Claims 7-10, drawn to a photolithographic system for processing a substrate comprising a substrate mount, classified in Class 354, subclass 228+.

VI. Claims 11-14, drawn to a method for exposing a photoresist, classified in Class 430, subclass 270.

VII. Claims 17-18, drawn to a system comprising a source of uncollimated and unfocused illumination and a means for illuminating a substrate, classified in Class 354, subclass 228.

VIII. Claim 19, drawn to a photolithographic system comprising a means of positioning one system above another, classified in Class 354, subclass 234.

IX. Claim 20, drawn to a method comprising positioning one photolithographic system above another, classified in Class 354, subclass 234.

X. Claim 21, drawn to a photolithographic system comprising the loading, alignment and exposure means set forth in the claim, classified in Class 354, subclass 234.

XI. Claim 22, drawn to a method for aligning a rectangular substrate on a substrate mount, classified in Class 354, subclass 234.

XII. Claim 23, drawn to a system used for aligning a rectangular substrate on a substrate mount, classified in Class 354, subclass 234.

XIII. Claims 24-29, drawn to a substrate mount, classified in Class 354, subclass 230.

XIV. Claims 30-31, drawn to a method for manufacturing a substrate mount, classified in Class 354, subclass 230.

XV. Claim 32, drawn to a mask mount comprising a transparent beam to be used in a photolithographic system, classified in Class 354, subclasses 229-230.

XVI. Claim 33, drawn to a method for positioning a mask on a substrate in a photolithographic system, classified in Class 354, subclass 234.

XVII. Claim 34, drawn to a mask mount comprising a mask flexure, classified in Class 354, subclass 230.

XVIII. Claims 35-36, drawn to a combined mask mount and substrate mount, classified in Class 354, subclass 230.

XIX. Claim 37, drawn to a mask used in a photolithographic system comprising a plate with beveled edges, classified in Class 430, subclass 5.

XX. Claim 38, drawn to a mask comprising a concavity on the surface, classified in Class 430, subclass 5.

XXI. Claim 39, drawn to a mask comprising a downward protruding perimeter rim member, classified in Class 430, subclass 5.

XXII. Claim 40, drawn to a mask comprising means to provide apressurized gas into the mask, classified in Class 430, subclass 5.