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ILLUMINANCE METER, ILLUMINANCE MEASURING METHOD USING THEREWITH AND EXPOSURE APPARATUS

BACKGROUND OF THE INVENTION



Field of the Invention

G00002

The present invention relates to an illuminance probe for measuring a level of energy of exposure light radiating on a substrate stage, and a method of measurements and exposure apparatus using the illuminance probe.

Description of the Related Art

For manufacturing semiconductor device elements, liquid crystal display elements, image pickup devices (CCD) and thin magnetic heads by photolithography, an exposure apparatus has been used conventionally to imprint a pattern fabricated on a reticle by projecting an exposure light through the reticle, functioning as a masking, onto a photo-sensitive substrate base represented by a wafer (or glass plate) coated with photo-resist in normal cases.

The exposure light source in such an exposure apparatus is excimer laser or mercury lamp, and an illuminance probe is used to determine illuminance or integrated exposure level radiating on the photo-sensitive base. Conventionally, a probe with a pin hole window and an optical sensor is placed by the operator on a wafer stage holding the photo-sensitive base, and the meter body comprised by the probe and the instrument base is connected to the illuminance probe to perform illuminance measurements. In such an operation, the operator must bring the wafer stage within the reach so that the probe can be placed on the wafer stage, move the wafer stage under the projection optics and carry out measurements of illuminance or integrated exposure level.

However, because the design requirements on the bus lines in the wafer have become finer in recent years, numerical aperture of the projection lens (optical projection system) is tending to become larger while the working distance between the projection lens and the wafer holder is tending to become narrower.

Also, along with finer bus lines in the circuit, requirements for precise alignment and the emergence of scanning type exposure apparatus have caused the wafer stage to be located lower in the exposure apparatus for vibration prevention.

In the meantime, wafer is likely to become larger from productivity considerations, which have caused the x-y stage for providing the stepping action to become larger and move in a larger area.

For these reasons, it has become more difficult for the operator to manually place the illuminance probe on the x-y stage under the current situation, and furthermore, the operator is forced into awkward posture to perform such operations. Also, because the working distance has become shorter, limitation is imposed on the probe height and there is increased danger of the operator accidentally hitting the optical components when moving the x-y stage.

SUMMARY OF THE INVENTION

The foregoing problems are resolved in the present invention by adopting the following structure. That is, the present invention is explained in the following by affixing reference numerals to various elements illustrated in Figs. 1~8.

An illuminance meter (8, 21, 31, 41) of the present invention is the illuminance meter for measuring an energy level of a radiation (L) illuminating a substrate (W) held on a substrate stage (WST) by means of a holding device (substrate holder WH). The meter comprises an instrument plate (9, 22, 32, 42) to be interchanged with the holding device and attached to a holder attachment section of the holding device on the substrate stage, a clamping section (9b, 24a) which couples with a holder clamping unit of a holder exchanger which is provided for the purpose of replacing an used holding device with another holding device; and an optical sensor (9a, 23) disposed on the instrument plate for responding to the radiation.

Furthermore, a illuminating method of the present invention is the method for measuring an energy level of a radiation illuminating a substrate (W) held on a holding device (substrate holder WH) attached on a substrate stage (WST). The method comprises the steps of transporting an illuminance meter (8, 21, 31, 41) for measuring an energy level by means of a clamping section (9b, 24a) of the illuminance meter; exchanging the holding device with the illuminance meter to position the illuminance meter on the substrate stage to measure the energy level; and detecting the radiation by means of the illuminance meter to obtain energy information on the energy level of the radiation.

Furthermore, an exposure apparatus of the present invention is the apparatus for exposure a substrate (W) with a radiation to project an image of a pattern of a mask on the substrate. The

apparatus comprises a substrate stage (WST), a holding device (substrate holder WH) attached on the substrate stage so as to hold the substrate; and a holder exchanger (11, 44) which detaches the holding device from the substrate stage, transports an illuminance meter by means of a clamping section (9b, 24a) provided on the illuminance meter and retains the illuminance meter on a holder attaching section of the substrate stage to detect the radiation.

Furthermore, an exposure method of the present invention is the method for exposing a substrate (W) with a radiation to imprint an image of a pattern of a mask on the substrate held on a holding device (substrate holder WH) attached on a substrate stage (WST). The method comprises the steps of transporting an illuminance meter (8, 21, 31, 41) to measure the energy level by means of a clamping section (9b, 24a) provided on the illuminance meter; removing the holding device by the clamping section to position the illuminance meter on the substrate stage; obtaining energy information of the radiation by detecting the radiation with the illuminance meter; detaching the illuminance meter from the substrate stage by the clamping section; attaching the substrate holder on the substrate stage; positioning the substrate on the substrate holder and; calibrating a sensor for measuring the radiation in accordance with the detected energy information.

Furthermore, a holding device of the present invention is the holding device for holding a substrate (W). The device comprises a holding section (WC) that holds the substrate and is interchangeably disposed on a substrate stage (WST) which is movable in a two-dimensional plane; and a clamping section (WB) disposed on the holding section for coupling with a holder clamping unit of a holder exchanger which is provided for the purpose of replacing an used holding device with another holding device.

As described above, in the present invention, since the illuminance meter or the substrate holder has the clamping section, the substrate holder can be exchanged easily and the mechanism for the exchange can be miniaturized.

It should be noted that "same size", mentioned in connection with following description of the present invention, does not infer dimensional exactness, such that it is quite adequate if the shape and size of the instrument plate are similar to those of the two components to be exchanged for, i.e., wafer and wafer holder, so that the exchange process can be carried out using the wafer exchanger arm of a wafer transport system.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is an overall schematic diagram of the illuminance meter, a method for measuring illuminance and an exposure apparatus using the illuminance meter.

Fig. 2 is a perspective view of an illuminance meter and a system for measuring illuminance based on the use of the illuminance meter in Embodiment 1.

Fig. 3 is a perspective view of an illuminance meter and a system for measuring illuminance using a holder exchanger of the exposure apparatus in Embodiment 1.

Fig. 4 is a perspective view of an illuminance meter and a system for using the illuminance meter in Embodiment 2.

Fig. 5 is a perspective view of an illuminance meter and a system for using the illuminance meter in Embodiment 3.

Fig. 6 is a plan view of a double-wafer type illuminance meter and a method for using the illuminance meter and a wafer stage of the exposure apparatus in Embodiment 4.

Fig. 7 is perspective view of an illuminance meter and a method for using the illuminance meter of the exposure apparatus in Embodiment 4.

Fig. 8 is a flowchart for an example of the semiconductor device manufacturing based on the use of the illuminance meter of the present invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Embodiment 1

An illuminance meter in Embodiment 1, a method of determining illuminance and an exposure apparatus based on the use of the illuminance meter, with reference to Figs. 1~3.

In these diagrams, reference numeral 1 relates to an exposure light source; 2 to an optical projection system; 8 to an illuminance meter; 9 to a probe; PL to a projection optical system; WST to a wafer stage; and WH to a wafer stage.

Fig. 1 shows a schematic view of the overall arrangement of a projection exposure system using the present illuminance meter.

The projection exposure system operates by holding the reticle (masking) R on the reticle stage RST and illuminating the reticle RST uniformly with a radiation emitted from an exposure light

source 1 so as to project an image of the pattern fabricated on the reticle R on a wafer (substrate) W coated with a photo-sensitive material through a protection optical system PL.

In the present projection exposure apparatus, the exposure light IL emitted from the exposure light source 1 is reflected by a mirror M1 is entered in the illumination optical system 2.

The illumination optical system 2 is comprised by: a relay lens 2a; an optical integrator (flyeye lens and others) 2b for homogenizing the exposure light IL; a mirror M2; an input lens (not shown) for injecting the exposure light IL in the optical integrator 2b; a relay lens (not shown) for focusing the exposure light IL output from the integrator 2b on the reticle R; and a condenser lens 2c.

The exposure light IL output from the illumination optical system 2 is entered in the reticle R held on the reticle stage RST, and after passing through the reticle R, the exposure light IL is entered in the projection optical system PL, and is radiated on the wafer W through several lenses comprising the projection optical system, and forms an image of the reticle R on the surface of the wafer W.

The reticle stage RST is disposed on top of a reticle base (not shown) and a reticle R is held on its top surface by vacuum suction, for example. The reticle stage RST can be positioned in a two-dimensional plane (x-y plane) which is perpendicular to the optical axis of the illumination optical system for micro-positioning of the reticle R by means of a reticle stage motor 3.

Here, the position of the reticle stage RST is constantly monitored by means of a laser interferometer 3b by monitoring a reflected beam reflecting from a moving mirror 3a fixed on the reticle stage RST.

The wafer W is placed on a wafer holder WH that is fixed on a wafer stage WST capable of being adjusted in three directions (x-, y- and z-directions).

Here, the position of the wafer stage WST in the x-y plane is constantly being monitored by the laser interferometer 4b that measures the position of the laser beam reflected from the moving mirror 4a fixed on the wafer stage WST.

The wafer stage WST is moved in steps by the wafer stage motor 5 according to the measured positional values of the interferometer 4b so as to carry out successive exposure of the pattern on the wafer W according to the so-called step-and-repeat method of exposing the wafer W.

Also, a focusing system comprised by a projection part 6a and a detector part 6b is provided above the wafer stage WST to optically detect the height of the wafer W, so that the projection part 6a emit an incident beam at an oblique angle to the surface of the wafer W, and the beam reflected from

the surface of the wafer W is detected by the detector part 6b so as to determine the height of the wafer W according to the reflected signal and to move the wafer stage WST in the appropriate direction to adjust the focus of the projection optical system PL.

Further, an illuminance level sensor 7 is disposed on the wafer stage WST to measure transmittance of the reticle R and other optical parameters. The illuminance level sensor 7 has a light receiving surface that is larger than the size of the illumination region radiating on the wafer stage WST so as to enable to determine the illumination level of the illumination light.

The wafer holder WH is detachably disposed on the wafer stage WST so that the probe (instrument plate) 9 of the illuminance meter 8 can be installed on the wafer stage WST instead of the wafer holder WH. That is, as shown in Fig. 2, the illuminance meter 8 is used to determine a level of energy of the exposure light IL radiating on the wafer W by means of the optical sensor 9a provided on the wafer holder WH mounted on the wafer stage WST, and is comprised by the probe 9 having the optical sensor 9a and a meter body 10 for computing a value of illuminance. The probe 9 is made in the same size as the wafer holder WH.

That is, the probe 9 has a light receiving window 9c in the center region so that the center of an optical sensor 9a whose sensing area is sufficiently large to receive refracted rays in relation to the numerical aperture (NA) of the projection lens and the working distance, will be disposed directly below the window 9c. Further, a clamping block (clamping section) 9b to fit the hook on the wafer holder WH is provided in a periphery of the probe 9a. Also, a cable 10a connected to the external meter body 10 is provided for sending detected signals to the meter body 10.

The illuminance meter 8, shown in Fig. 2, is a so-called reference meter for maintaining the level of detection precision of the illuminance level sensor 7, and the results obtained by the illuminance level sensor 7 are calibrated against the results obtained by the illuminance meter 8. Such calibration operation is performed periodically (once a week, for example) to maintain the detection precision of the illuminance level sensor 7. By sharing the results produced by the illuminance meter 8 among the different exposure apparatuses, exposure levels within a given duration of exposure are made interchangeable among the various exposure apparatuses.

As shown in Fig. 3, the exposure apparatus is further provided with a holder exchanger (attaching/detaching mechanism, holder transport mechanism) 11 on a column 12 of the exposure

apparatus, for detaching and exchanging the holder including the wafer holder WH and the probe 9 on the wafer stage WST.

The holder exchanger 11 is provided for the purpose of replacing an used wafer holder WH with another wafer holder WH, and, instead of the wafer holder WH, the probe 9 having the same size as the wafer holder WH can also be transported thereon.

The wafer holder 11 is designed so that the holder clamping unit 14 can be moved along the x-guide section 15 by pushing the x-lever 13 in the x-direction shown in Fig. 3, until the plunger (not shown) locks the position of the wafer holder WH or the probe 9 along the x-direction, and it can be retracted to a standby position by pulling the x-lever 13 frontward.

Also, by pushing the z-lever 16 downward, the holder clamping unit 14 is moved along the z-guide section 17, and the wafer holder WH or the probe 9 can be lowered to the clamping position by catching the z-lever 16 on the lever stop (not shown). Further, a micro-z-adjust bolt (not shown) is provided so as to avoid touching the AF cover (not shown) and optical sensors. Micro-adjustment of rotation in x-y plane (θ -adjustment) is performed by rotating the x-lever 13 in θ -direction.

The wafer holder WH or the probe 9 is clamped by rotating the x-lever 13 about its axis, and using the hooking section 14a of the holder clamping unit 14 for the wafer holder WH or the probe 9 to hook on the clamping block so as to lock the clamping hook (not shown) to prevent the wafer holder WH or the probe 9 from dropping.

The procedure for exchanging the wafer holder WH or the probe 9 using the holder exchanger 11 is as follows: the holder exchanger 11 is attached to the column 12 of the exposure apparatus, the vacuum holding the wafer holder WH on the wafer stage WST is cut for detachment, the wafer holder WH is moved to the clamping position using the x-lever 13, and the holder exchanger 11 is lowered to the clamping position using the z-lever 16.

Next, the clamping block (clamping section) WB provided on the outer periphery of the base chucking section WC of the wafer holder WH is clamped by swinging the x-lever 13, and the wafer holder WH is fixed in position by using the lock, and the wafer holder WH is pulled into the standby position by pulling the x-lever 13 while floating the wafer holder WH by the z-lever 16. The lock is released at this point, and the wafer holder WH is detached by rotating the x-lever 13 in the opposite direction.

To install the probe 9 on the wafer stage WST, the above procedure is reversed. Accordingly, the probe 9 is mechanically positioned in a specified position on the wafer stage 28 as in the case of positioning the wafer holder WH.

To measure illuminance or integrated exposure level on the wafer surface using the illuminance meter 8 after exchanging the wafer holder WH with the probe 9 using the holder exchanger 11, the wafer stage WST is moved from the holder exchange position to the lower section of the projection optical system PL so that the light receiving window 9c is positioned in a desired position within the illumination region, so as to radiate the illumination light on the wafer stage WST through the illumination optical system 2 and the projection optical system PL. At this time, exposure light entering through the window 9c is received in the optical sensor 9a, and the signals generated according to the energy of the exposure light are sent to the meter body 10 through the cable 10a to compute a value of illuminance. Because the size of the window 9c is several tens of micrometers, the method of mechanical positioning on the wafer stage WST described above is acceptable for placing the probe 9 in the illumination region with sufficient precision.

Accordingly, in this embodiment, because illuminance is measured with the probe 9 of the illuminance meter having the same size as the wafer holder WH, and the probe 9 is positioned by exchanging the wafer holder WH with the probe 9 using the holder exchanger 11 on the wafer stage WST, the operator does not need to position the probe manually on the wafer stage WST and the probe 9 can be positioned on the wafer stage WST easily but with high precision.

Embodiment 2

The illuminance meter, illuminance measuring method and exposure apparatus in Embodiment 2 will be explained with reference to Fig. 4.

Embodiment 2 differs from Embodiment 1 in the following point. The optical sensor 9a itself in Embodiment 1 has the same size as the wafer holder WH, but the illuminance meter 21 in Embodiment 2 has an optical sensor 23a as a separate member of a probe 22, as shown in Fig. 4, and the optical sensor 23 is attached to an adapter 24 of the same size as the wafer holder WH.

In other words, the probe 22 is comprised by an adapter 24 of the same size as the wafer holder WH and a clamping block (clamping section) 24a as a part of the probe 22, and a rectangular shaped optical sensor 23 inserted in a cavity section 24b formed in the center region of the adapter 24.

The upper surface of the optical sensor 23 is shaded from light except in the center window 23a, and is further provided with a cable 10a connected to the meter body 10 for transmitting signals to the meter body 10.

The adapter 24 has a groove section 24c extending from the cavity section 24b to the periphery for embedding the cable 10a.

In this embodiment, because the probe 22 is separated from the optical sensor 23 and the adapter of the same size as the wafer holder WH is used to attach to the optical sensor 23, the optical sensor 23 can be detached from the adapter 24 for use in carrying out other measurements, and there is no need to fabricate the sensor itself in the same size as the wafer holder WH.

Embodiment 3

The illuminance meter, illuminance measuring method and exposure apparatus in Embodiment 3 will be explained with reference to Fig. 5.

Embodiment 3 differs from Embodiment 2 in the following point. The probe 22 in Embodiment 2 converts incident light energy radiating on the optical sensor 23 into electrical signals, which are sent to the external meter body 10 through a cable 10a, while the illuminance meter 31 in Embodiment 3 transmits electrical signals (information regarding the exposure light energy) from the optical sensor 23 by infra-red signals to the meter body 30 as illustrated in Fig. 5.

That is, the adapter 34 of the probe 32 incorporates internally: an A/D converter circuit 34a, for converting the electrical signals from the optical sensor 23 to digital signals; a light emitting element (sending mechanism) 34b for sending converted signals externally from the A/D converter circuit 34a from its peripheral section; and a power section 34c comprised by a battery for supplying electrical power to the optical sensor 23, the A/D converter circuit 34a and the light emitting element 34b.

Also, the external meter body 30 is provided with a light detecting element (receiving means) 30a for receiving light signals from the light emitting element 34b, and the light detecting element 30a is disposed in a location suitable for receiving light signals emitted from the probe 32 positioned on the wafer stage WST. Here, the exposure apparatus in this embodiment is provided with a wafer stage WST for mounting and transport of the probe 32 of the illuminance meter 31.

In this embodiment, exposure light injected into the optical sensor 23 is converted to electrical signals, which are converted to digital signals in the A/D converter circuit 34a, and the converted

signals are wirelessly transmitted from the light emitting element 34b through space and are received by the external light detecting element 30a, so as to compute a value of illuminance in the meter body 30.

Accordingly, cable is unnecessary for transmitting light signals, thereby facilitating handling of the probe 32, and enabling accurate signals to be transmitted because digitized optical signals are used as communication medium, thereby lessening adverse effects caused by electromagnetic interference. Also, because the A/D converter circuit 34a, the light emitting element 34b and the power section 34c are housed inside the adapter 34, overall shape of the probe 34 can be made the same as the wafer holder WH so as to be interchangeable with the wafer holder WH.

In this embodiment, a photo-electric device for charging the battery, a solar panel for example, may be positioned in a location on the surface of the adapter 34 not occupied by the optical sensor 23. Battery can be changed before or concurrently with taking energy measurements using the optical sensor 23, by utilizing the solar panel to absorb the energy of the exposure light.

Such an arrangement eliminates the task of battery charging, and the probe 32 can continue to work for a prolonged period of time in the exposure apparatus.

Embodiment 4

The illuminance meter, illuminance measuring method and exposure apparatus in Embodiment 4 will be explained with reference to Figs. 6 and 7.

Embodiment 4 differs from Embodiment 1 in the following points. The exposure apparatus in Embodiment 1 has one wafer stage 28 while the exposure apparatus in Embodiment 4 has a double-stage structure comprised by two wafer stages WST1, WST2, as shown in Fig. 6.

Another difference is that, in Embodiment 1, the probe 9 has the same size as the wafer holder WH but in Embodiment 4, the probe 42 is comprised by an optical sensor 43 having the same size as the wafer W, and at least one of the wafer stages WST1, WST2 can accommodate probe 42 as well as the wafer W. The double stage structure has been disclosed in a Japanese Patent Application, First Publication, Hei 10-163097.

The top surface of the optical sensor 43 is shielded from light except at the light receiving window 43a, and a cable 10a is connected for sending signals to an external meter body 10, as in Embodiment 1.

The exposure apparatus operates as follows. The wafer stages WST1, WST2 can be moved independently in two-dimensions on a base (not shown) so that while one wafer stage WST1 is used to expose a wafer W, the other wafer stage WST2 is used for exchanging the exposed wafer W with the probe 42 by means of the load arm 44a of the wafer loader (load/unload mechanism, base transport mechanism, illuminance meter transport means) 44. In a manner similar to the case of exposing a wafer W, the light receiving window 43a is positioned in a specific spot on the wafer stage (WST1 or WST2) by means of a pre-alignment device (not shown). In this embodiment also, because the size of the light receiving window 43a is several tens of micrometers, the probe can be positioned with sufficient precision in a specific spot within the illumination region of the wafer stage using the pre-alignment device.

Therefore, in this embodiment, loss of productivity caused by interruption due to measuring of exposure light energy can be prevented by using two wafer stages WST1, WST2 to carry out two tasks independent of the other, i.e., the wafer/probe exchange task and the wafer exposure task. Also, because the probe 42 of the illuminance meter 41 has the same size as the wafer W, it enables to easily exchange the wafer W with the probe 42 on the wafer stage WST2 using the wafer loader 44. When the probe 42 is replaced with a wafer W, devices such as optical sensor and signal processing circuit can be fabricated on the wafer using photolithography.

It should be noted that the present invention includes the following variations.

(1) In the illuminance meters 8, 21, 31 presented in Embodiments 1~3, probes 9, 22, 23 have the same size as the wafer holder WH so as to enable the probe to be interchangeable with the wafer holder WH using the holder exchanger 11, but, as demonstrated by the illuminance meter 41 in Embodiment 4, the probes in these embodiments may have the same size as the wafer W so that probe/wafer exchange may be carried out using a wafer transport mechanism such as the wafer loader.

Also, in Embodiment 4, the probe 42 of the illuminance meter 41 may have the same size as the wafer holder WH so that probe/holder exchange on the wafer stages WST1, WST2 may be carried out using the holder exchanger 11.

(2) In Embodiment 3, signals are transmitted using infra-red radiation using light emitting element 34b and light detecting element 30a, but other methods of wireless transmission based on

electrical waves may also be used. However, infra-red transmission of signals is preferable in terms of avoiding electromagnetic interference effects, as mentioned earlier.

(3) In Embodiments 1~3, a manually-operated holder exchanger 11 is used, but an automated holder exchanger may also be used. For example, various axes of the holder exchanger 11 may be electrically operated by using actuators such as motors, or as disclosed in a Japanese Patent Application, First Publication, Hei 9-266166, jigs and robots may be used to install/exchange the wafer holder on the wafer stage.

(4) In the embodiments presented above, an illuminance meter is used to determine illuminance or integrated exposure level on the image plane of the wafer stage, but the illuminance meter may be used as a light intensity sensor for determining the uniformity of light in the illumination space. In such a case, the illuminance meter which is normally disposed in a corner of the wafer stage should be moved to a central location of the wafer stage so that the travel distance of the light intensity sensor would be greatly reduced.

(5) The present invention may also be applied to a scanning type exposure apparatus, in which case, mask and substrate will be moved synchronously during the exposure process in these embodiments.

The present invention may also be applied to a proximity type exposure apparatus, in which the projection system is not used, and the masking and the substrate are in close contact during the exposure process for imprinting the making pattern on the substrate.

(6) In each of the embodiments presented above, the illuminance meter (8, 21, 31, 41) is designed so that, when the illuminance meter having roughly the same size as the wafer holder (or wafer) is placed on the wafer stage WST (or wafer holder WH), the thickness of the illuminance meter is selected such that the top surface (or incident surface) is at about the same height as the surface of the wafer W. Therefore, by placing the wafer stage WST at a specific height, the surface of the illuminance meter will be at about the same height as the focusing plane of the projection optical system for measuring the exposure light IL.

However, even if the illuminance meter has other thickness value, the surface of the illuminance meter can be positioned at about the same height as the image plane of the projection optical system by determining the height of the illuminance meter surface and moving the wafer stage WST vertically to the same height according to the measured result.

(7) The use of the exposure apparatus is not limited to semiconductor device production. Other uses include, for example, exposure apparatus for imprinting circuit patterns for liquid crystal display panel on rectangular glass plates or for producing thin film magnetic heads.

(8) The light source of the exposure apparatus in the present invention may include x-rays in addition to g-line (436 nm), i-line (365 nm), KrF excimer laser (248 nm), ArF excimer laser (193 nm), F2 laser (157 nm).

(9) The projection optical system may include contact imprinting and enlarging imprinting in addition to reducing imprinting.

(10) Optical materials for projection optical systems based on extreme ultraviolet rays such as excimer lasers may include quartz and fluorite for transmitting extreme ultraviolet radiation, and for F2 laser and x-rays, reflective/refractive systems or refractive systems (reticle is also made of a reflective type material) may be used.

(11) If linear motors are to be used in wafer stage and reticle stage, either air-levitated type based on air bearings, or a magnetically levitated type based on a Lorentz force or a reactance force may be used. The stages may be a guided type that moves a stage along guide rails or a guideless type with no guides.

(12) When a planar motor is to be used for stage moving mechanism, either the magnetic unit (permanent magnet) or the armature unit is installed on the stage, and the other component of the magnetic unit or armature unit may be installed on the moving surface (base) of the stage.

(13) The reactant force generated by the movement of the wafer stage may be dissipated mechanically to the floor (ground) through the framing members, as disclosed in a Japanese Patent Application, First Publication, Hei 8-166475. The present invention is applicable to an exposure apparatus having such a structure.

(14) The reactant force generated by the movement of the reticle stage may be dissipated mechanically to the floor (ground) through the framing members, as disclosed in a Japanese Patent Application, First Publication, Hei 8-330224. The present invention is applicable to an exposure apparatus having such a structure.

(15) As described above, the exposure apparatus of the present invention is manufactured by assembling various sub-systems, that include the various structural elements disclosed in the claims of the present invention, so as to maintain the required degrees of mechanical, electrical and optical

precision. To achieve the required degrees of precision in the various sub-systems, apparatus assembly operation are preceded and followed by various inspection/adjustment steps to assure optical precision of the optical systems, mechanical precision of the mechanical systems, and electrical precision of the electrical systems. Assembly of the exposure system is preceded by assembling of various sub-systems to respective specification, so that the exposure apparatus may be assembled by mutual connections of sub-systems involving mechanical connections, wiring of electrical circuits and connections associated with pressure piping. When the final assembly of sub-systems into an exposure apparatus is completed, individual sub-systems are adjusted within the operating environment of the overall adjustments to assure overall precision of the exposure apparatus. Assembly operation for the exposure apparatus should be performed in a cleanroom environment.

(16) A semiconductor device is produced by the exposure apparatus of the present invention according to a typical flowchart shown in Fig. 8, represented by: step 201 to design functions and capabilities of the device; step 202 to produce a masking pattern (reticle) according to the design; step 203 to produce wafers from silicon ingot; step 204 to process the wafers according to the procedure described to imprint the pattern on the wafer using the exposure apparatus; step 205 to assemble a device (such as dicing, bonding, packaging and other processes); and step 206 to inspect the assembled device.

What is claimed is:

1. An illuminance meter which measures an energy level of a radiation illuminating a substrate held on a substrate stage by means of a holding device, comprising:
 - an instrument plate to be interchanged with the holding device and attached to a holder attachment section of the holding device on the substrate stage;
 - a clamping section which couples with a holder clamping unit of a holder exchanger which is provided for the purpose of replacing an used holding device with another holding device; and
 - an optical sensor disposed on the instrument plate for responding to said radiation.
2. An illuminance meter according to claim 1, wherein said illuminance meter is able to be interchanged with a holding device by the holder exchanger.
3. An illuminance meter according to claim 1, wherein said instrument plate and said holding device have a same size, and said clamping section protrudes from an external periphery of the instrument plate.
4. An illuminance meter according to claim 1, wherein said instrument plate is provided with a holding section so as to be attached on a substrate stage by means of vacuum suction.
5. An illuminance meter according to claim 1, wherein said instrument plate is provided with a wireless transmitting device for externally transmitting information related to levels of radiation energy obtained by an optical sensor.
6. An illuminance meter according to claim 1, wherein said illuminance meter is provided with a battery and a photo-electric converter for charging the battery.
7. An illuminance meter according to claim 1, wherein said illuminance meter is used to determine individual energy levels of exposure light emitted from a plurality of exposure apparatuses so that said individual energy levels are interchangeable among the plurality of exposure apparatuses.

8. A method for measuring an energy level of a radiation illuminating a substrate held on a holding device attached on a substrate stage, comprising the steps of:
 - transporting an illuminance meter by means of a clamping section of the illuminance meter;
 - exchanging the holding device with the illuminance meter to position the illuminance meter on the substrate stage to measure an energy level; and
 - detecting said radiation by means of the illuminance meter to obtain energy information on the energy level of said radiation.
9. A method according to claim 8, wherein positioning of said illuminance meter is carried out by means of a holder exchanger which is provided for the purpose of replacing an used holding device with another holding device.
10. A method according to claim 8, wherein said method further includes a step of vacuum chucking of an illuminance meter on a substrate stage.
11. A method according to claim 8, wherein said method further includes a step of wireless transmission of energy information on energy levels determined.
12. A method according to claim 8, wherein said illuminance meter determines individual energy levels of exposure light emitted from a plurality of exposure apparatuses so that said individual energy levels can be used interchangeably among the plurality of exposure apparatuses.
13. A method according to claim 8, wherein said method further includes a step of determining positional information with respect to a direction of emission of radiation; and a step of adjusting a position of the illuminance meter according to results of said positional information.
14. An apparatus which exposes a substrate with a radiation to project an image of a pattern of a mask on the substrate, comprising:
 - a substrate stage;

a holding device attached on said substrate stage so as to hold said substrate; and
a holder exchanger which detaches said holding device from said substrate stage, transports an illuminance meter by means of a clamping section provided on said illuminance meter and retains said illuminance meter on a holder attaching section of said substrate stage to detect said radiation.

15. A method for exposing a substrate with a radiation to imprint an image of a pattern of a mask on said substrate held on a holding device attached on a substrate stage, comprising the steps of:

transporting an illuminance meter having an optical sensor responsive to said radiation by means of a clamping section provided on the illuminance meter;

removing said holding device by means of the clamping section so as to position and retain said illuminance meter on the substrate stage;

obtaining energy information of said radiation by detecting said radiation with said illuminance meter;

detaching said illuminance meter from the substrate stage by said clamping section;

attaching said substrate holder on the substrate stage;

positioning said substrate on the substrate holder and;

calibrating a sensor for measuring said radiation in accordance with the detected energy information.

16. A method for making semiconductor devices by exposing a substrate using the method of exposure according to claim 15, and producing semiconductor devices from the exposed substrate.

17. A holding device which holds a substrate, comprised by:

a holding section that holds the substrate, the holding section is interchangeably disposed on a substrate stage which is movable in a two-dimensional plane; and

a clamping section disposed on the holding section for coupling with a holder clamping unit of a holder exchanger which is provided for the purpose of replacing an used holding device with another holding device.