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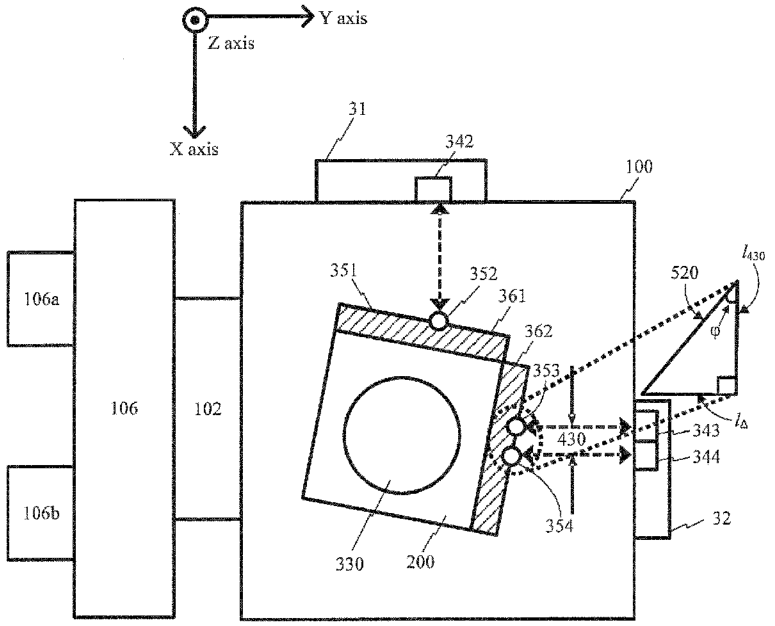

Fig. 5

(57) **Abstract:** System and method for dynamically determining a position of stage (200) holding a sample and automatically compensating position errors comprising a plurality of interferometer units (31, 32) configured to generate signals based on a position of a stage and further comprising a computing device which can be configured to determine the position of the sample based on the signals, and in response to the determined position, provide instructions associated with the determined position by a control module for controlling of a motor of a stage, or for controlling of a motor to adjust interferometer units emitting charged particle beams, or combination thereof, to compensate position errors of a sample automatically.

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SYSTEM AND METHOD FOR DETERMINING AND CALIBRATING A POSITION OF A STAGE

CROSS-REFERENCE TO RELATED APPLICATIONS

[001] This application claims priority of US provisional application 62/413,551, which was filed on October 27, 2016, and US provisional application 62/571,085, which was filed on October 10, 2017, both of which are incorporated herein in their entirety by reference.

TECHNICAL FIELD

[002] The present disclosure generally relates to systems and methods for dynamically determining a position of stage holding a sample and automatically making any calibrations based on the determined position.

BACKGROUND

[003] In manufacturing processes of integrated circuits (ICs), unfinished or finished circuit components are inspected to ensure that they are manufactured according to design and are free of defects. An inspection system utilizing an optical microscope typically has resolution down to a few hundred nanometers; and the resolution is limited by the wavelength of light. As the physical sizes of IC components continue to reduce down to a sub-100 or even sub-10 nanometers, inspection systems capable of higher resolution than those utilizing optical microscopes are needed.

[004] A charged particle (for example, an electron) beam microscope, such as a scanning electron microscope (SEM) or a transmission electron microscope (TEM), capable of achieving resolution down to less than a nanometer, serves as a practicable tool for inspecting IC components having a feature size that is sub-100 nanometers. With an SEM, electrons of a single primary electron beam, or electrons of a plurality of primary electron beams, can be focused at one or more scan locations of a stage under inspection. The primary electrons interact with a surface and may be backscattered or may cause the surface to emit secondary electrons. The quality (e.g. intensity) of the electron beams comprising the secondary electrons may vary based on the properties (e.g. reflective rate, distance to destination) of the external structures of the surface. Detecting the quality of the electron beams facilitates the determination of the position of a stage.

[005] At atmospheric pressure, the charged particles (e.g., electrons) suffer frequent collisions with gas molecules and are deflected from their path. The mean free path of charged particles at atmospheric pressure can be too small for practical inspection applications. A chamber housing a charged particle beam microscope is therefore evacuated to a low pressure value (high vacuum level) before using the charged particle beam for inspection.

[006] When a sample wafer is deposited on a stage configured to hold sample in a high vacuum level chamber for processing, the position of the stage decides the position of the sample wafer. Position errors, however, can occur to the stage holding a sample in the chamber space. The position errors can cause misprocessing of the wafer. This makes it critical to determine the position of the stage and calibrate its position with errors corrected. Further, the efficiency of such determining and calibrating affects the throughput of the manufacturing process.

SUMMARY

[007] Embodiments of the present disclosure provide systems and methods for dynamically determining position of stage holding a sample and automatically making any calibrations based on the determined position of the stage. In some embodiments, a system is provided. The system comprises a control module configured to evaluate a position of a stage based on a first distance and a second distance measured from a first side of the stage relative to a first side of a chamber and a third distance measured from a second side of the stage relative to a second side of the chamber. The control module is further configured to provide instructions to adjust the position of the stage or one or more charged particle beams based on the evaluated position.

[008] In some embodiments, a method for determining a position of a stage in a chamber and further calibrating the position of a stage of sample is provided. The method comprises evaluating a position of a stage based on a first distance and a second distance measured from a first side of the stage relative to a first side of a chamber and a third distance measured from a second side of the stage relative to a second side of the chamber. The method further comprises providing instructions to adjust the position of the stage or one or more charged particle beams based on the evaluated position.

[009] In some embodiments, a non-transitory computer readable storage medium storing a set of instructions that is executable by one or more processors of a computing device to cause the computing device to perform a method is provided. The method comprises evaluating a position of a stage based on a first distance and a second distance measured from a first side of the stage relative to a first side of a chamber and a third distance measured from a second side of the stage relative to a second side of the chamber. The method further comprises providing instructions to adjust the position of the stage or one or more charged particle beams based on the evaluated position.

[010] Additional objects and advantages of the disclosed embodiments will be set forth in part in the following description, and in part will be apparent from the description, or may be learned by practice of the embodiments. The objects and advantages of the disclosed embodiments may be realized and attained by the elements and combinations set forth in the claims.

[011] It is to be understood that both the foregoing general description and the following detailed description are exemplary and explanatory only and are not restrictive of the disclosed embodiments, as claimed.

BRIEF DESCRIPTION OF THE DRAWINGS

[012] **FIG. 1** is a schematic diagram illustrating an exemplary electron beam inspection (EBI) system, consistent with embodiments of the present disclosure.

[013] **FIG. 2** is a schematic diagram illustrating an exemplary electron beam tool that can be a part of the exemplary electron beam inspection system of **FIG. 1**, consistent with embodiments of the present disclosure.

[014] **FIG. 3A** is a schematic diagram illustrating an exemplary system using distance measurement components for determining a position of a stage, consistent with embodiments of the present disclosure.

[015] **FIGs. 3B** and **3C** are schematic diagrams illustrating an exemplary unit having distance measurement components for determining a position of a stage, consistent with embodiments of the present disclosure.

[016] **FIGs. 4A** and **4B** are schematic diagrams illustrating exemplary side views of the first and second reflective surface of a stage receiving electron beams from distance measurement components of interferometer units, consistent with embodiments of the present disclosure.

[017] **FIG. 5** is a schematic diagram illustrating the exemplary system of **FIG. 3** using distance measurement components for determining the position of the stage, consistent with embodiments of the present disclosure.

[018] **FIG. 6** is a flowchart illustrating an exemplary method for determining a position of a stage, consistent with embodiments of the present disclosure.

[019] **FIG. 7** is a flowchart illustrating an exemplary method for determining a position of a stage, consistent with embodiments of the present disclosure.

[020] **FIG. 8** is a flowchart illustrating an exemplary method for determining a position of a stage, consistent with embodiments of the present disclosure.

DESCRIPTION OF THE EMBODIMENTS

[021] Reference will now be made in detail to exemplary embodiments, examples of which are illustrated in the accompanying drawings. The following description refers to the accompanying drawings in which the same numbers in different drawings represent the same or similar elements unless otherwise represented. The implementations set forth in the following description of exemplary embodiments do not represent all implementations consistent with the invention. Instead, they are merely examples of apparatuses and methods consistent with aspects related to the invention as recited in the appended claims.

[022] The present disclosure relates to systems and methods for dynamically evaluating a

position of stage holding a sample and, based on the evaluated position, making any appropriate adjustments, such as automatically adjusting the position of the stage or one or more charged particle beams. For example, the present disclosure provides a plurality of distance measurement devices (e.g., interferometers) configured to generate signals based on a position of a stage and a computing system comprising a control module configured to evaluate the position of the stage. In response to the determined position, the system can be configured to provide instructions for adjusting the position of the stage or one or more charged particle beams based on the evaluated position. Any stage position errors can be detected and corrections can be made without the wafer being unloaded and reloaded, thereby improving the throughput of the manufacturing process.

[023] Reference is now made to **FIG. 1**, which illustrates an exemplary position determining and calibrating system 1 with an electron beam inspection (EBI) system 10 consistent with embodiments of the present disclosure. As shown in **FIG. 1**, position determining and calibrating system 1 includes an EBI system 10 and a control module 11 that is communicatively couple to EBI system 10. EBI system 10 includes a main chamber 100, a load/lock chamber 102, an electron beam tool 104, and an equipment front end module (EFEM) 106. Electron beam tool 104 is located within main chamber 100.

[024] EFEM 106 includes a first loading port 106a and a second loading port 106b. EFEM 106 may include additional loading port(s). First loading port 106a and second loading port 106b receive wafer front opening unified pods (FOUPs) that contain wafers (e.g., semiconductor wafers or wafers made of other material(s)) or samples to be inspected (wafers and samples are collectively referred to as “wafers” hereafter). One or more robot arms (not shown) in EFEM 106 transport the wafers to load/lock chamber 102.

[025] Load/lock chamber 102 is connected to a load/lock vacuum pump system (not shown), which removes gas molecules in load/lock chamber 102 to reach a first pressure below the atmospheric pressure. After reaching the first pressure, one or more robot arms (not shown) transport the wafer from load/lock chamber 102 to main chamber 100. Main chamber 100 is connected to a main chamber vacuum pump system (not shown), which removes gas molecules in main chamber 100 to reach a second pressure below the first pressure. After reaching the second pressure, the wafer is subject to inspection by electron beam tool 104. While the present disclosure provides examples of main chamber 100 housing an electron beam inspection system, it should be noted that aspects of the disclosure in their broadest sense, are not limited to a chamber housing an electron beam inspection system. Rather, it is appreciated that the forgoing principles may be applied to other chambers as well.

[026] While **FIG. 1** shows control module 11 being separate from EBI system 10, it is appreciated that control module 11 can be part of EBI system 10. Control module 11 can use data regarding the position of a stage to make any appropriate adjustments to the stage or the electron beam. Control module can be a packaged functional hardware unit designed for use with other components (e.g., portions of an integrated circuit) or a part of a program (stored on a computer readable medium) that

performs a particular function of related functions. The control module can have entry and exit points and can be written in a programming language, such as, for example, Java, Lua, C or C++. A software-based control module can be compiled and linked into an executable program, installed in a dynamic link library, or written in an interpreted programming language such as, for example, BASIC, Perl, or Python. It will be appreciated that the software-based module can be callable from other modules, and/or can be invoked in response to detected events or interrupts. The software-based module configured for execution can be provided on a computer readable medium, such as a compact disc, digital video disc, flash drive, magnetic disc, or any other non-transitory medium, or as a digital download (and can be originally stored in a compressed or installable format that requires installation, decompression, or decryption prior to execution). Such software code can be stored, partially or fully, on a memory device of the executing computing device, for execution by the computing device. Software instructions can be embedded in firmware, such as an EPROM. It will be further appreciated that a hardware-based control module can be comprised of connected logic units, such as gates and flip-flops, and/or can be comprised of programmable units, such as programmable gate arrays or processors.

[027] Reference is now made to **FIG. 2**, which illustrates exemplary components of electron beam tool 104 consistent with embodiments of the present disclosure. As shown in **FIG. 2**, electron beam tool 104 includes a stage 200, and a wafer holder 202 supported by stage 200 to hold a wafer 203 to be inspected. Electron beam tool 104 further includes an objective lens assembly 204, electron detector 206, an objective aperture 208, a condenser lens 210, a beam limit aperture 212, a gun aperture 214, an anode 216, and a cathode 218. Objective lens assembly 204, in some embodiments, can include a modified swing objective retarding immersion lens (SORIL), which includes a pole piece 204a, a control electrode 204b, a deflector 204c, and an exciting coil 204d. Electron beam tool 104 may additionally include an energy dispersive X-ray spectrometer (EDS) detector (not shown) to characterize the materials on the wafer.

[028] A primary electron beam 220 is emitted from cathode 218 by applying a voltage between anode 216 and cathode 218. Primary electron beam 220 passes through gun aperture 214 and beam limit aperture 212, both of which can determine the size of electron beam entering condenser lens 210, which resides below beam limit aperture 212. Condenser lens 210 focuses primary electron beam 220 before the beam enters objective aperture 208 to set the size of the electron beam before entering objective lens assembly 204. Deflector 204c deflects primary electron beam 220 to facilitate beam scanning on the wafer. For example, in a scanning process, deflector 204c can be controlled to deflect primary electron beam 220 sequentially onto different locations of top surface of wafer 203 at different time points, to provide data for image reconstruction for different parts of wafer 203. Further, in some embodiments, anode 216 and cathode 218 can be configured to generate multiple primary electron beams 220, and electron beam tool 104 can include a plurality of deflectors 204c to project the multiple primary electron beams 220 to different portions of the wafer at the same time, to provide data for image reconstruction for different portions of wafer 203.

[029] Exciting coil 204d and pole piece 204a generate a magnetic field that begins at one end of pole piece 204a and terminates at the other end of pole piece 204a. A part of wafer 203 being scanned by primary electron beam 220 can be immersed in the magnetic field and can be electrically charged, which, in turn, creates an electric field. The electric field reduces the energy of impinging primary electron beam 220 near the surface of the wafer before it collides with the wafer. Control electrode 204b, being electrically isolated from pole piece 204a, controls an electric field on the wafer to prevent micro-arching of the wafer and to ensure proper beam focus.

[030] A secondary electron beam 222 can be emitted from the part of wafer 203 upon receiving primary electron beam 220. Secondary electron beam 222 can form a beam spot on sensor surfaces of electron detector 206. Electron detector 206 can generate a signal (e.g., a voltage, a current, etc.) that represents an intensity of the beam spot, and provide the signal to a processing system (not shown in **FIG. 2**). The intensity of secondary electron beam 222, and the resultant beam spot, can vary according to the external and/or internal structure of wafer 203. Moreover, as discussed above, primary electron beam 220 can be projected onto different locations of the surface of the wafer, to generate secondary electron beams 222 (and the resultant beam spot) of different intensities. Therefore, by mapping the intensities of the beam spots with the locations of wafer 203, the processing system can reconstruct an image that reflects the internal and/or external structures of wafer 203.

[031] Reference is now made to **FIG. 3A**, which is a schematic diagram illustrating distance measurement components 341, 342, 343, 344, and 345 used for detecting the position of a stage 200 wafer 330, consistent with embodiments of the present disclosure. Wafer 330 can be present in a chamber (e.g., main chamber 100 of **FIG. 1**) and supported by a wafer holder 202 (as shown in **FIG. 2**) on top of stage 200. Stage may include a plurality of reflective surfaces 361 and 362, such as a mirror. Reflective surfaces 361 and 362 of stage 200 and the beam spots formed on the surfaces of the drawing may not be proportional, in order to more clearly depict certain features of the disclosed invention in accordance with embodiments of the present disclosure. Moreover, reflective surfaces 361 and 362 may be on sides of stage 200 facing the distance measurement components 341, 342, 343, 344, and 345.

[032] As shown in **FIG. 3A**, a first set of distance measurement devices 341 and 342 are part of a first unit 31 and a second set of distance measurement devices 343-345 are part of a second unit 32. Units 31 and 32 can be, for example, one or more interferometers. First unit 31 supplies the measuring light beams for measuring along the first reflective surface 361 of the stage 200, and second unit 32 supplies the measuring light beams for measuring along the second reflective surface 362 of the stage 200. Alternatively, more than two interferometer units may also be used for detecting distances to surfaces of the stage in accordance with embodiments of the present disclosure. For example, while **FIG. 3A** shows that distance measurement components 341 and 342 are part of unit 31 and distance measurement components 343-345 are part of another unit 32, it is appreciated that each of distance measurement components 341-345 may be standalone devices (e.g., each component corresponds to a

separate interferometer). Moreover, it is appreciated that a pair of corresponding distance measurement components (e.g., distance measurement components 341 and 342, distance measurement components 343 and 344, distance measurement components 344 and 345, and distance measurement components 343 and 345) can be included within a single differential component, such as differential interferometer that measures the distance between the interferometer and corresponding light spots on reflective surface of stage.

[033] Further, it is appreciated that **FIG. 3A** is a simplistic X-Y planar illustration of the general layout of the distance measurement components with respect to stage 200, it is understood that distance measurement component 341 is at least displaced from distance measurement component 342 in the Z-axis (as shown in **FIG. 3B**). That is, distance measurement component 341 can be stacked on top of distance measurement component 342. Accordingly, distance measurement components 341 and 342 can be configured to face first reflective surface 361 of stage 200 and be apart from each other along the Z-axis.

[034] Moreover, it is understood that distance measurement component 345 is at least displaced from distance measurement components 343 and 344 in the Z-axis (as shown in **FIG. 3C**). That is, distance measurement component 345 can be stacked on top of at least one of distance measurement component 344 and 343. Accordingly, distance measurement components 343, 344, and 345 can be configured to face second reflective surface 362 of stage 200. Further, distance measurement component 343 can be configured to be displaced from at least one of distance measurement components 344 and 345 along the X-axis.

[035] Distance measurement components can be configured to emit a light spot, which can reach reflective surface of the stage. The intersection of light spots and the two surface of the stage are labeled as 351, 352, 353, 354, and 355 in **FIG. 3A**, in which 351 and 352 are light spots formed on reflective surface 361, and 353, 354, and 355 are light spots formed on the reflective surface 362. Reflective light can be reflected from the surfaces of a stage upon receiving the light spots. Distance measurement components 341-345 can receive their respective reflective light and generate a signal that can be provided to a computing device and control module 11 (not shown in **FIG. 3A**). The intensity of the reflective light can vary according to the distance between the surface of a stage and the distance measurement component, which uses the reflective intensity to determine an accurate value of the distance.

[036] The one or more signals received by control module 11 can include the determined distance by each distance measurement device or raw data that would allow control module 11 to determine the distances. Using these distances (as further explained below), control module 11 can provide instructions to adjust the position of stage 200 or the position of one or more charged particle beams based on the evaluated position

[037] Reference is now made to **FIG. 4A**, which is a schematic diagram illustrating a side view

of the first reflective surface 361 of stage 200 receiving a light beams emitted from distance measurement components 341 and 342 (as shown in **FIG. 3A-B**) and forming light spots 351 and 352 respectively, consistent with embodiments of the present disclosure. Distance measurement components 341 and 342 are offset at a first displacement distance 410 along Z-axis. Hence, the two light beams emitted from distance measurement components 341 and 342 are also configured to be apart at a first displacement distance 410 and are in parallel to each other in the Z-plane. While the combination of **FIG. 3A** and **FIG. 4A** shows that beam spots 351 and 352 are aligned on the Y-axis, it is appreciated that beam spot 351 and 352 can be offset along the Y-axis so long as the displacement distance is predetermined.

[038] Reference is now made to **FIG. 4B**, which is a schematic diagram illustrating a side view of the second reflective surface 362 of a stage receiving light beams emitted from distance measurement components 343, 344, and 345 (as shown in **FIGs. 3A, 3C**) and forming light spots 353, 354, and 355 by the three light beams respectively, consistent with embodiments of the present disclosure. Distance measurement component 345 is displaced from at least one of distance measurement components 343 and 344 at a second displacement distance 420 along the Z-axis. Hence, the light beams emitted from distance measurement component 345 and from at least one distance measurement components 343 and 344 are also configured to be apart at a first displacement distance 420 and are in parallel in the Z-plane.

[039] Further, distance measurement component 343 is displaced from at least one of distance measurement components 344 and 345 at a third displacement distance 430 along the X-axis. Hence, the light beams emitted from distance measurement component 343 and from at least one distance measurement components 344 and 345 are also configured to be apart at a first displacement distance 430 and are in parallel in the X-plane.

[040] Reference is now made to **FIG. 5**, which is a schematic diagram illustrating stage 200 being rotated from the original point in XY-plane (e.g. a shift along the X-Y axes), consistent with embodiments of the present disclosure. For purposes of simplicity, since device measuring components 341 and 345 are displaced in the Z-direction (and their corresponding light spots 351 and 355), they have been removed for explaining how to determine the position of the stage in the X-Z plane and Y-Z plane, which can be determined using device measuring components 342, 343, and 344.

[041] As illustrated in **FIG. 5**, distance measurement component 342 can generate data for determining a distance l_{342} along the X-axis from distance measurement component 342 to light spot 352 formed on a first reflective surface 361. It is appreciated that distance l_{342} can be determined by one or more of control module 11, distance measurement component 342, and unit 31.

[042] Moreover distance measurement components 343 and 344 can generate data for determining distances l_{343} and l_{344}, respectively, along the Y-axis to beam spots 353 and 354 formed on second reflective surface 362. It is appreciated that the distances can be determined by one or more of control module 11, distance measurement components 343 and 344, and unit 32. If distances l_{343} and l_{344} are different, the difference in length (l_{Δ}) between the distances l_{343} and l_{344} can be determined. Using

length l_Δ and displacement distance (l_{430}) between distance measurement components 343 and 344, a rotation angle φ_{x-y} of right triangle 520 having an adjacent length of l_{430} and an opposite length of l_Δ can be determined along the X-Y plane as follows:

$$\tan \varphi_{x-y} = \frac{l_\Delta}{l_{430}}, \qquad (1)$$

where φ_{x-y} is the rotation angle in the X-Y plane. Using rotation angle φ_{x-y}, distance l_{342}, and at least one of distances l_{343} and l_{344}, the position of the stage (relative to the X-Y plane of the chamber) can be determined by control module 11. Moreover, it is appreciated that in other embodiments, the rotation angle φ_{x-y} of right triangle 520 can be defined as having an adjacent length of l_Δ and an opposite length of l_{430}.

[043] While distance measurement components 341 and 345 were removed for purposes of simplicity, it is appreciated that any rotation of the stage in the Z-direction (φ_{y-z}, φ_{x-z}) can be detected using a determination similar to that described above. That is, any determined difference in measuring distances between two distance measurement components (e.g., l_{341} and l_{342} or l_{345} and l_{344}), where one of the components is displaced from the other component at a distance in the Z-direction, can be used to detect a rotation in the Z-direction. For example at unit 31, if a difference in distance is detected between l_{341} and l_{342}, a right triangle similar to right triangle 520 having the difference and the displacement distance (l_{410}) between two distance measurement components 341, 342 can be used for determining rotation angle φ_{x-z}. Moreover, at unit 32, if a difference in distance is detected between l_{345} and l_{344}, a right triangle similar to right triangle 520 having the difference and the displacement distance (l_{420}) between two distance measurement components 345, 344 can be used for determining rotation angle φ_{y-z}.

[044] Control module 11 can use distances l_{341}, l_{342}, l_{343}, l_{344}, and l_{345} and/or rotation angles φ_{x-y}, φ_{y-z}, φ_{x-z} to determine the position of stage 200 relative to the chamber. Based on the determined position, control module can provide instructions to adjust the position of the stage or the positioning of the one or more charged particle beams relative to the position of the stage.

[045] Reference is now made to **FIG. 6**, illustrating an exemplary method 60 for determining a position of a stage and making calibrations according to the position, consistent with embodiments of the present disclosure. Method 60 can be performed by a system using a plurality of distance measurement components (e.g., distance measurement components 342-344) and a control module (e.g., control module 11). Using method 60, the system can determine a position of a stage in an X-Y plane relative to a chamber (e.g., chamber 100).

[046] In step 610, system can measure a first distance to a first side of a stage. For example, as shown above in **FIG. 5**, distance measurement component 343 can measure the distance l_{343} between component 343 and corresponding light spot 353 on reflective surface 362 of stage 200.

[047] Referring back to **FIG. 6**, in step 620, system can measure a second distance to a second

side of the stage. For example, as shown above in **FIG. 5**, distance measurement component 342 can measure the distance l_{342} between component 342 and corresponding light spot 352 on reflective surface 361 of stage 200.

[048] Referring back to **FIG. 6**, in step 630, system can measure a third distance to the first side of the stage. For example, as shown above in **FIG. 5**, distance measurement component 344 can measure the distance l_{344} between component 344 and corresponding light spot 354 on reflective surface 362 of stage 200.

[049] Referring back to **FIG. 6**, it is appreciated that steps 610, 620, 630 can happen in any order or can occur at the same time. It is also appreciated that steps 610, 620, 630 can occur at the distance measurement components (or at units housing the distance measurement components), or that the distance measurement components can provide raw data to the control module for determining the measurement of the distances. Moreover, it is appreciated that a pair of corresponding distance measurement components (e.g., distance measurement components 343 and 344) can included within a single differential component, such as differential interferometer that measures the distance between the interferometer and corresponding points on reflective surface of stage. Accordingly, steps 610 and 630 could be updated or be replaced with receiving the difference distance l_{Δ} , which could then be used later to determine the position of the stage.

[050] In step 640, system can determine a position of the stage using the measured distances. In particular, the control module of the system can use the distance information to determine the position of the stage. For example, in situations where the first distance and the third distance are the same (or where the difference distance is 0), the control module can determine the position of the stage using only these distances.

[051] If, however, the first distance and the third distance are different (or there is a difference distance other than 0), the control module may need to utilize other information to determine the position of the stage. For example, if needed, the control module can determine the difference distance (e.g., difference distance l_{Δ}) between the first and third distances. Moreover, the control module can access displacement distance (e.g., displacement distance l_{430}) representing the distance between the distance measurement components performing steps 610 and 630. This displacement distance information is readily accessible to the control module and may be stored locally to the control module. Using the displacement distance and the difference distance, the control module can determine the rotation angle of the stage using Equation (1) above and accordingly the position of the stage relative to some defined reference point (e.g., the layout of the chamber).

[052] In step 650, if needed, the system can make adjustments based on the determined position of the stage. Based on the determined position of the stage, the control module can provide instructions for repositioning the stage via, for example, a robotic arm or motor moving the stage, and/or for updating the positioning of one or more beams to be focused on a wafer placed on the stage.

[053] Reference is now made to **FIG. 7**, illustrating an exemplary method 70 for determining a position of a stage and making calibrations according to the position, consistent with embodiments of the present disclosure. Method 70 can be performed by a system using a plurality of distance measurement components (e.g., distance measurement components 341-343 and 345) and a control module (e.g., control module 11). Using method 70, the system can determine a position of a stage in three-dimensional space relative to a chamber (e.g., chamber 100).

[054] In step 710, system can measure a first distance to a first side of a stage. For example, as shown above in **FIG. 3A**, distance measurement component 343 can measure the distance l_{343} between component 343 and corresponding light spot 353 on reflective surface 362 of stage 200.

[055] Referring back to **FIG. 7** in step 720, system can measure a second distance to a second side of the stage. For example, as shown above in **FIG. 3A**, distance measurement component 342 can measure the distance l_{342} between component 342 and corresponding light spot 352 on reflective surface 361 of stage 200.

[056] Referring back to **FIG. 7**, in step 730, system can measure a third distance to the first side of the stage. For example, as shown above in **FIGs. 3A and 3C**, distance measurement component 345 can measure the distance l_{345} between component 345 and corresponding light spot 355 on reflective surface 362 of stage 200. As shown in **FIG. 3C**, distance measurement component 345 is displaced from distance measurement component 343 in both the X and Z directions.

[057] Referring back to **FIG. 7** in step 740, system can measure a fourth distance to a second side of the stage. For example, as shown above in **FIGs. 3A and 3B**, distance measurement component 341 can measure the distance l_{341} between component 341 and corresponding light spot 351 on reflective surface 361 of stage 200. As shown in **FIG. 3B**, distance measurement component 341 is displaced from distance measurement component 342 in at least the Z direction.

[058] Referring back to **FIG. 7**, it is appreciated that steps 710, 720, 730, and 740 can happen in any order or can occur at the same time. It is also appreciated that steps 710, 720, 730, and 740 can occur at the distance measurement components (or at units housing the distance measurement components), or that the distance measurement components can provide raw data to the control module for determining the measurement of the distances. Moreover, it is appreciated that a pair of corresponding distance measurement components (e.g., distance measurement components 341 and 342, distance measurement components 343 and 344, distance measurement components 344 and 345, and distance measurement components 343 and 345) can be included within a single differential component, such as differential interferometer that measures the distance between the interferometer and corresponding points on reflective surface of stage. For example, steps 710 and 730 could be replaced with or be updated to include receiving a difference distance, which could then be used later to determine the position of the stage.

[059] In step 750, system can determine a position of the stage using the measured distances. In

particular, the control module of the system can use the distance information to determine the position of the stage. For example, in situations where the first distance and the third distance are the same and the second distance and fourth distance are also the same, the control module can determine the position of the stage using only the first, second, third, and fourth distances.

[060] If, however, the first distance and the third distance are different and/or the second and fourth distances are different, the control module may need to utilize other information to determine the position of the stage. For example, the control module can determine any difference distances between the first and third distances (e.g., difference distance between l_{343} and l_{355}) and between the second and fourth distances (e.g., distance between l_{341} and l_{342}). Moreover, the control module can access any relevant displacement distances, such as displacement distance l_{410} between the distance measurement components performing steps 720 and 740 and the displacement distances in both the X and Z direction of the distance measurement components performing steps 710 and 730. This displacement distance information is readily accessible to the control module and may be stored locally to the control module. Using one or more of the displacement distances and one or more of the difference distances, the control module can determine one or more rotation angles ($\varphi_{x-y}, \varphi_{y-z}, \varphi_{x-z}$) of the stage using Equation (1) above and accordingly the position of the stage relative to some defined reference point (e.g., the layout of the chamber).

[061] In step 760, if needed, the system can make adjustments based on the determined position of the stage. Based on the determined position of the stage, the control module can provide instructions for repositioning the stage via, for example, a robotic arm or motor moving the stage, and/or for updating the positioning of one or more beams to be focused on a wafer placed on the stage.

[062] Reference is now made to **FIG. 8**, illustrating an exemplary method 80 for determining a position of a stage and making calibrations according to the position, consistent with embodiments of the present disclosure. Method 80 can be performed by a system using a plurality of distance measurement components (e.g., distance measurement components 341- 345) and a control module (e.g., control module 11). Using method 80, the system can determine a position of a stage in three-dimensional space relative to a chamber (e.g., chamber 100).

[063] In step 810, system can measure a first distance to a first side of a stage. For example, as shown above in **FIG. 3A**, distance measurement component 343 can measure the distance l_{343} between component 343 and corresponding light spot 353 on reflective surface 362 of stage 200.

[064] Referring back to **FIG. 8** in step 820, system can measure a second distance to a second side of the stage. For example, as shown above in **FIG. 3A**, distance measurement component 342 can measure the distance l_{342} between component 342 and corresponding light spot 352 on reflective surface 361 of stage 200.

[065] Referring back to **FIG. 8**, in step 830, system can measure a third distance to the first side of the stage. For example, as shown above in **FIGs. 3A and 3C**, distance measurement component 344

can measure the distance l_{344} between component 344 and corresponding light spot 354 on reflective surface 362 of stage 200. As shown in **FIG. 3C**, distance measurement component 344 is displaced from distance measurement component 343 in the X direction.

[066] Referring back to **FIG. 8** in step 840, system can measure a fourth distance to a second side of the stage. For example, as shown above in **FIGs. 3A and 3B**, distance measurement component 341 can measure the distance l_{341} between component 341 and corresponding light spot 351 on reflective surface 361 of stage 200. As shown in **FIG. 3B**, distance measurement component 341 is displaced from distance measurement component 342 in at least the Z direction.

[067] Referring back to **FIG. 8**, in step 850, system can measure a fifth distance to the first side of the stage. For example, as shown above in **FIGs. 3A and 3C**, distance measurement component 345 can measure the distance l_{345} between component 345 and corresponding light spot 355 on reflective surface 362 of stage 200. As shown in **FIG. 3C**, distance measurement component 345 is displaced from distance measurement component 344 in at least the Z directions and from distance measurement component 343 in at least the X direction.

[068] Referring back to **FIG. 8**, it is appreciated that steps 810, 820, 830, 840 and 850 can happen in any order or can occur at the same time. It is also appreciated that steps 810, 820, 830, 840 and 850 can occur at the distance measurement components (or at units housing the distance measurement components), or that the distance measurement components can provide raw data to the control module for determining the measurement of the distances. Moreover, it is appreciated that a pair of corresponding distance measurement components (e.g., distance measurement components 341 and 342, distance measurement components 343 and 344, and distance measurement components 344 and 345) can be included within a single differential component, such as differential interferometer that measures the distance between the interferometer and corresponding points on reflective surface of stage. Accordingly, for example, steps 810 and 830 could be replaced with or be updated to include receiving a difference distance (e.g., difference distance l_{Δ}), which could then be used later to determine the position of the stage.

[069] In step 860, system can determine a position of the stage using the measured distances. In particular, the control module of the system can use the distance information to determine the position of the stage. For example, in situations where the first distance and the third distance are the same and the second distance and fourth distance are also the same, the control module can determine the position of the stage using only the first, second, third, and fourth distances.

[070] If, however, the first distance and the third distance are different and/or the second and fourth distances are different, the control module may need to utilize other information to determine the position of the stage. For example, the control module can determine any difference distances between the first and third distances (e.g., difference distance l_{Δ}), between the second and fourth distances (e.g., distance between l_{341} and l_{342}), and between third and fifth distances (e.g., distance between l_{345} and l_{344}).

Moreover, the control module can access any relevant displacement distances (e.g., displacement distances l_{430}, l_{410}, and l_{420}) representing the distance between the distance measurement components performing steps 810 and 830, performing steps 820 and 840, and performing steps 830 and 850. This displacement distance information is readily accessible to the control module and may be stored locally to the control module. Using one or more of the displacement distances and one or more of the difference distances, the control module can determine one or more rotation angles ($\varphi_{x-y}, \varphi_{y-z}, \varphi_{x-z}$) of the stage using Equation (1) above and accordingly the position of the stage relative to some defined reference point (e.g., the layout of the chamber).

[071] In step 870, if needed, the system can make adjustments based on the determined position of the stage. Based on the determined position of the stage, the control module can provide instructions for repositioning the stage via, for example, a robotic arm or motor moving the stage, and/or for updating the positioning of one or more beams to be focused on a wafer placed on the stage.

[072] The embodiments may further be described using the following clauses:

1. A system comprising:

a control module configured to:

evaluate a position of a stage based on:

a first distance and a second distance measured from a first side of the stage relative to a first side of a chamber;

a third distance measured from a second side of the stage relative to a second side of the chamber; and

provide instructions to adjust the position of the stage or of one or more charged particle beams based on the evaluated position.

2. The system of clause 1, further comprising:

a first distance measurement device positioned relative to the first side of the chamber and configured to measure the first distance;

a second distance measurement device positioned relative to the first side of the chamber and configured to measure the second distance, wherein the second distance measurement device is horizontally displaced from the first distance measurement device by a first displacement distance; and

a third distance measurement device positioned relative to the second side of the chamber and configured to measure the third distance.

3. The system of clause 2, wherein the evaluation of the position of the stage comprises the control module being further configured to:

determine position of the stage relative to a first axis based on a difference between the first distance and the second distance, and the first displacement distance.

4. The system of clauses 2 or 3, wherein the evaluation of the position of the stage comprises the control module being further configured to:

determine position of the stage relative to a second axis based on a difference between the first distance and the second distance, and the first displacement distance.

5. The system of any one of clauses 1-4, wherein the control module is further configured to:

evaluate the position of the stage based on a fourth distance measured from the second side of the stage relative to the second side of the chamber.

6. The system of clause 5, further comprising:

a fourth distance measurement device positioned relative to the second side of the chamber and configured to measure the fourth distance, wherein the fourth distance measurement device is vertically displaced from the third distance measurement device by a second displacement distance.

7. The system of clauses 5 or 6, wherein the evaluation of the position of the stage comprises the control module being further configured to:

determine position of the stage relative to a first axis based on a difference between the first distance and the second distance, and the first displacement distance;

determine position of the stage relative to a second axis based on a difference between the first distance and the second distance, and the first displacement distance; and

determine position of the stage relative to a third axis based on a difference between the third distance and the fourth distance, and the second displacement distance.

8. The system of any one of clauses 5-7, wherein the control module is further configured to:

evaluate the position of the stage based on a fifth distance measured from the first side of the stage relative to the first side of the chamber.

9. The system of clause 8, further comprising:

a fifth distance measurement device positioned relative to the first side of the chamber and configured to measure the fifth distance, wherein the fifth distance measurement device is vertically displaced from the first distance measurement device by a third displacement distance.

10. The system of clauses 8 or 9, wherein the evaluation of the position of the stage comprises the control module being further configured to:

determine position of the stage relative to a first axis based on a difference between the first distance and the second distance, and the first displacement distance;

determine position of the stage relative to a second axis based on a difference between the third distance and the fourth distance, and the second displacement distance; and

determine position of the stage relative to a third axis based on a difference between the first distance and the fifth distance, and the third displacement distance.

11. The system of any one of clauses 9 and 10, wherein the evaluation of the position of the stage comprises the control module being further configured to:

determine the position of the stage relative to the third axis based on a difference between the third distance and the fourth distance, and the second displacement distance.

12. The system of any one of clauses 1-11, wherein the first side of the chamber is perpendicular to the second side of the chamber; and a third side of the chamber is perpendicular to the first side of the chamber and to the second side of the chamber.

13. The system of clause 12, wherein:

the second distance measurement device is positioned in alignment with the first distance measurement device along an axis perpendicular to the second side of the chamber;

the fourth distance measurement device is positioned in alignment with the third distance measurement device along an axis perpendicular to the third side of the chamber; and

the fifth distance measurement device is positioned in alignment with the first distance measurement device along an axis perpendicular to the third side of the chamber.

14. The system of any one of clauses 1-13, wherein one or more of the first distance measurement device, the second distance measurement device, the third distance measurement device, the fourth distance measurement device, and the fifth distance measurement device include laser interferometers,

15. The system of any one of clauses 2-14, wherein the measurement of the first distance and the second distance is based on a reflection, from one or more mirrored surfaces of the first side of the stage, of beams associated with the first and second measurement devices and the measurement of the third distance is based on a reflection, from a mirrored surface of the second side of the stage, of a beam associated with the third measurement device.

16. The system of any one of clauses 1-15, wherein the charged particle beam is an electron beam configured to inspect a wafer placed on the stage.

17. The system of clause 16, wherein adjustment of the charged particle beam comprises the control module being further configured to control an electron beam deflector to adjust a wafer inspection location.

18. The system of any one of clauses 9-17, wherein the positioning of one of the third distance measurement device and the fourth distance measurement device, and the positioning of one of the first distance measurement device, the second distance measurement device, and the fifth distance measurement device are aligned with reference to the charged particle beam.

19. The system of any one of clauses 9-18, further comprising a differential interferometer including at least one of a pair of the first distance measurement device and the second distance measurement device, of third distance measurement device and the fourth distance measurement device, of the first distance measurement device and the fourth distance measurement device, and of the first distance measurement device and the fifth distance measurement device.

20. A method comprising:

evaluating a position of a stage based on:

a first distance and a second distance measured from a first side of the stage relative to a first side of a chamber; and

a third distance measured from a second side of the stage relative to a second side of the chamber; and

providing instructions to adjust the position of the stage or of one or more charged particle beams based on the evaluated position.

21. The method of clause 20, wherein evaluating the position of the stage comprises:

receiving the first distance measured by a first distance measurement device positioned relative to the first side of the chamber;

receiving the second distance measured by a second distance measurement device positioned relative to the first side of the chamber and horizontally displaced from the first distance measurement device by a first displacement distance; and

receiving the third distance measured by a third distance measurement device positioned relative to the second side of the chamber.

22. The method of clause 21, wherein evaluating the position of the stage further comprises:

determining the position of the stage relative to a first axis based on a difference between the first distance and the second distance, and the first displacement distance.

23. The method of clauses 21 or 22, wherein evaluating the position of the stage further comprises:

determining the position of the stage relative to a second axis based on a difference between the first distance and the second distance, and the first displacement distance.

24. The method of any one of clauses 20-23, wherein:

evaluating the position of the stage is further based on a fourth distance measured from the second side of the stage relative to the second side of the chamber.

25. The method of clause 24, wherein evaluating the position of the stage further comprises:

receiving the fourth distance measured by a fourth distance measurement device positioned relative to the second side of the chamber and vertically displaced from the third distance measurement device by a second displacement distance.

26. The method of clauses 24 or 25, wherein evaluating the position of the stage further comprises:

determining the position of the stage relative to a first axis based on a difference between the first distance and the second distance, and the first displacement distance;

determining the position of the stage relative to a second axis based on a difference between the first distance and the second distance, and the first displacement distance; and

determining the position of the stage relative to a third axis based on a difference between the third distance and the fourth distance, and the second displacement distance.

27. The method of any one of clauses 20-26, wherein:

evaluating the position of the stage is further based on a fifth distance measured from the first side of the stage relative to the first side of the chamber.

28. The method of clause 27, wherein evaluating the position of the stage further comprises:

receiving the fifth distance measured by a fifth distance measurement device positioned relative to the first side of the chamber and vertically displaced from the first distance measurement device by a third displacement distance.

29. The method of clauses 27 or 28, wherein evaluating the position of the stage further comprises:

determining the position of the stage relative to a first axis based on a difference between the first distance and the second distance, and the first displacement distance;

determining the position of the stage relative to a second axis based on a difference between the third distance and the fourth distance, and the second displacement distance; and

determining the position of the stage relative to a third axis based on a difference between the first distance and the fifth distance, and the third displacement distance.

30. The method of clause 29, wherein evaluating the position of the stage further comprises:

determining the position of the stage relative to the third axis based on a difference between the third distance and the fourth distance, and the second displacement distance.

31. The method of any one of clauses 20-30, wherein the charged particle beam is an electron beam configured to inspect a wafer placed on the stage.

32. The method of clause 31, wherein providing instructions to adjust the position of the charged particle beam comprises controlling an electron beam deflector to adjust a wafer inspection location.

33. A non-transitory computer readable storage medium storing instructions that are executable by a computing device that includes one or more processors to cause the computing device to perform a method comprising:

evaluating a position of a stage based on:

a first distance and a second distance measured from a first side of the stage relative to a first side of a chamber; and

a third distance measured from a second side of the stage relative to a second side of the chamber; and providing instructions to adjust the position of the stage or of one or more charged particle beams based on the evaluated position.

34. The medium of clause 33, wherein evaluating the position of the stage comprises:

receiving the first distance measured by a first distance measurement device positioned relative to the first side of the chamber;

receiving the second distance measured by a second distance measurement device positioned relative to the first side of the chamber and horizontally displaced from the first distance measurement device by a first displacement distance; and

receiving the third distance measured by a third distance measurement device positioned relative to the second side of the chamber.

35. The medium of clause 34, wherein evaluating the position of the stage further comprises:

determining the position of the stage relative to a first axis based on a difference between the first distance and the second distance, and the first displacement distance.

36. The medium of clauses 34 or 35, wherein evaluating the position of the stage further comprises:

determining the position of the stage relative to a second axis based on a difference between the first distance and the second distance, and the first displacement distance.

37. The medium of any one of clauses 33-36, wherein:

evaluating the position of the stage is further based on a fourth distance measured from the second side of the stage relative to the second side of the chamber.

38. The medium of clause 37, wherein evaluating the position of the stage further comprises:

measuring the fourth distance by a fourth distance measurement device positioned relative to the second side of the chamber and vertically displaced from the third distance measurement device by a second displacement distance.

39. The medium of clauses 37 or 38, wherein evaluating the position of the stage further comprises:

determining the position of the stage relative to a first axis based on a difference between the first distance and the second distance, and the first displacement distance;

determining the position of the stage relative to a second axis based on a difference between the first distance and the second distance, and the first displacement distance; and determining the position of the stage relative to a third axis based on a difference between the third distance and the fourth distance, and the second displacement distance.

40. The medium of any one of clauses 33-39, wherein:

evaluating the position of the stage is further based on a fifth distance measured from the first side of the stage relative to the first side of the chamber.

41. The medium of clause 39, wherein evaluating the position of the stage further comprises:

receiving the fifth distance measured by a fifth distance measurement device positioned relative to the first side of the chamber and vertically displaced from the first distance measurement device by a third displacement distance.

42. The medium of clauses 40 or 41, wherein evaluating the position of the stage further comprises:

determining the position of the stage relative to a first axis based on a difference between the first distance and the second distance, and the first displacement distance;

determining the position of the stage relative to a second axis based on a difference between the third distance and the fourth distance, and the second displacement distance; and

determining the position of the stage relative to a third axis based on a difference between the first distance and the fifth distance, and the third displacement distance.

43. The medium of clause 42, wherein evaluating the position of the stage further comprises:

determining the position of the stage relative to the third axis based on a difference between the third distance and the fourth distance, and the second displacement distance.

44. The medium of any one of clauses 33-43, wherein the charged particle beam is an electron beam configured to inspect a wafer placed on the stage.

45. The medium of clause 44, wherein providing instructions to adjust the position of the charged particle beam comprises controlling an electron beam deflector to adjust a wafer inspection location.

[073] The dynamic calibrating process described above is configured to be automatically initiated upon completion of values of parameters of displacements by a computing device and receipt of commands from a control module. Hence, such adjustment and calibration can be configured to complete without loading and unloading the wafer on the stage. The accuracy of wafer transfer, the proficiency of loading, as well as the throughput of the process and yield of manufacturing are all improved.

[074] The block diagrams in the Figures illustrate the architecture, functionality, and operation of possible implementations of systems, methods, and computer hardware/software products according to

various exemplary embodiments of the present disclosure. It should also be understood that each block of the block diagrams, and combination of the blocks, can be implemented by special purpose hardware-based systems that perform the specified functions or acts, or by combinations of special purpose hardware and computer instructions.

[075] It will be appreciated that the present embodiments are not limited to the exact construction that has been described above and illustrated in the accompanying drawings, and that various modifications and changes can be made without departing from the scope thereof. It is intended that the scope of the invention should only be limited by the appended claims.

WHAT IS CLAIMED IS:

1. A system comprising:

a control module configured to:

evaluate a position of a stage based on:

a first distance and a second distance measured from a first side of the stage relative to a first side of a chamber;

a third distance measured from a second side of the stage relative to a second side of the chamber; and

provide instructions to adjust the position of the stage or of one or more charged particle beams based on the evaluated position.

2. The system of claim 1, further comprising:

a first distance measurement device positioned relative to the first side of the chamber and configured to measure the first distance;

a second distance measurement device positioned relative to the first side of the chamber and configured to measure the second distance, wherein the second distance measurement device is horizontally displaced from the first distance measurement device by a first displacement distance; and

a third distance measurement device positioned relative to the second side of the chamber and configured to measure the third distance.

3. The system of claim 2, wherein the evaluation of the position of the stage comprises the control module being further configured to:

determine position of the stage relative to a first axis based on a difference between the first distance and the second distance, and the first displacement distance.

4. The system of claim 2 , wherein the evaluation of the position of the stage comprises the control module being further configured to:

determine position of the stage relative to a second axis based on a difference between the first distance and the second distance, and the first displacement distance.

5. The system of claim 1, wherein the control module is further configured to:

evaluate the position of the stage based on a fourth distance measured from the second side of the stage relative to the second side of the chamber.

6. The system of claim 5, further comprising:

a fourth distance measurement device positioned relative to the second side of the chamber and configured to measure the fourth distance, wherein the fourth distance measurement device is vertically displaced from the third distance measurement device by a second displacement distance.

7. The system of claim 5, wherein the evaluation of the position of the stage comprises the control module being further configured to:

determine position of the stage relative to a first axis based on a difference between the first distance and the second distance, and the first displacement distance;

determine position of the stage relative to a second axis based on a difference between the first distance and the second distance, and the first displacement distance; and

determine position of the stage relative to a third axis based on a difference between the third distance and the fourth distance, and the second displacement distance.

8. The system of claim 5, wherein the control module is further configured to:

evaluate the position of the stage based on a fifth distance measured from the first side of the stage relative to the first side of the chamber, and/or

a fifth distance measurement device positioned relative to the first side of the chamber and configured to measure the fifth distance, wherein the fifth distance measurement device is vertically displaced from the first distance measurement device by a third displacement distance.

9. The system of claim 8, wherein the evaluation of the position of the stage comprises the control module being further configured to:

determine position of the stage relative to a first axis based on a difference between the first distance and the second distance, and the first displacement distance;

determine position of the stage relative to a second axis based on a difference between the third distance and the fourth distance, and the second displacement distance; and

determine position of the stage relative to a third axis based on a difference between the first distance and the fifth distance, and the third displacement distance, and/or

wherein the evaluation of the position of the stage comprises the control module being further configured to:

determine the position of the stage relative to the third axis based on a difference between the third distance and the fourth distance, and the second displacement distance.

10. The system of claim 1, wherein the first side of the chamber is perpendicular to the second side of the chamber; and a third side of the chamber is perpendicular to the first side of the chamber and to the second side of the chamber.

11. The system of claim 10, wherein:

the second distance measurement device is positioned in alignment with the first distance measurement device along an axis perpendicular to the second side of the chamber;

the fourth distance measurement device is positioned in alignment with the third distance measurement device along an axis perpendicular to the third side of the chamber; and

the fifth distance measurement device is positioned in alignment with the first distance measurement device along an axis perpendicular to the third side of the chamber.

12. The system of claim 1, wherein one or more of the first distance measurement device, the second distance measurement device, the third distance measurement device, the fourth distance measurement device, and the fifth distance measurement device include laser interferometers, and/or

wherein the measurement of the first distance and the second distance is based on a reflection, from one or more mirrored surfaces of the first side of the stage, of beams associated with the first and second measurement devices and the measurement of the third distance is based on a reflection, from a mirrored surface of the second side of the stage, of a beam associated with the third measurement device.

13. The system of claim 1, wherein the charged particle beam is an electron beam configured to inspect a wafer placed on the stage, and/or

wherein adjustment of the charged particle beam comprises the control module being further configured to control an electron beam deflector to adjust a wafer inspection location, and/or

wherein the positioning of one of the third distance measurement device and the fourth distance measurement device, and the positioning of one of the first distance measurement device, the second distance measurement device, and the fifth distance measurement device are aligned with reference to the charged particle beam.

14. A method comprising:

evaluating a position of a stage based on:

a first distance and a second distance measured from a first side of the stage relative to a first side of a chamber; and

a third distance measured from a second side of the stage relative to a second side of the chamber; and

providing instructions to adjust the position of the stage or of one or more charged particle beams based on the evaluated position.

15. A non-transitory computer readable storage medium storing instructions that are executable by a computing device that includes one or more processors to cause the computing device to perform a method of claim 14.

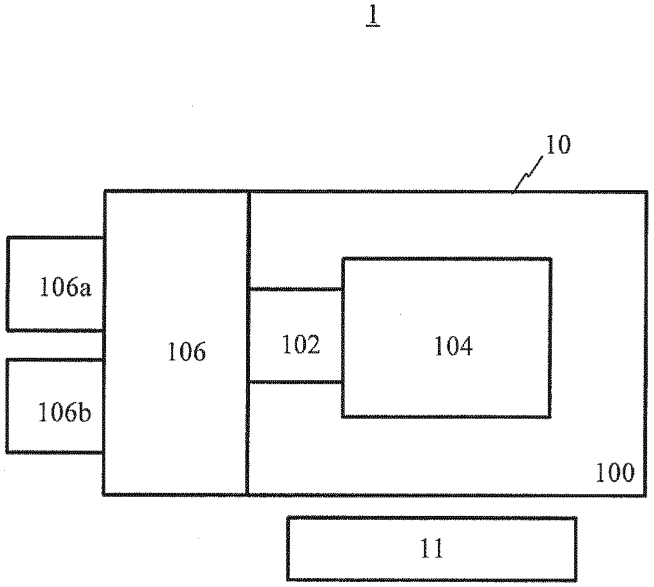


Fig. 1

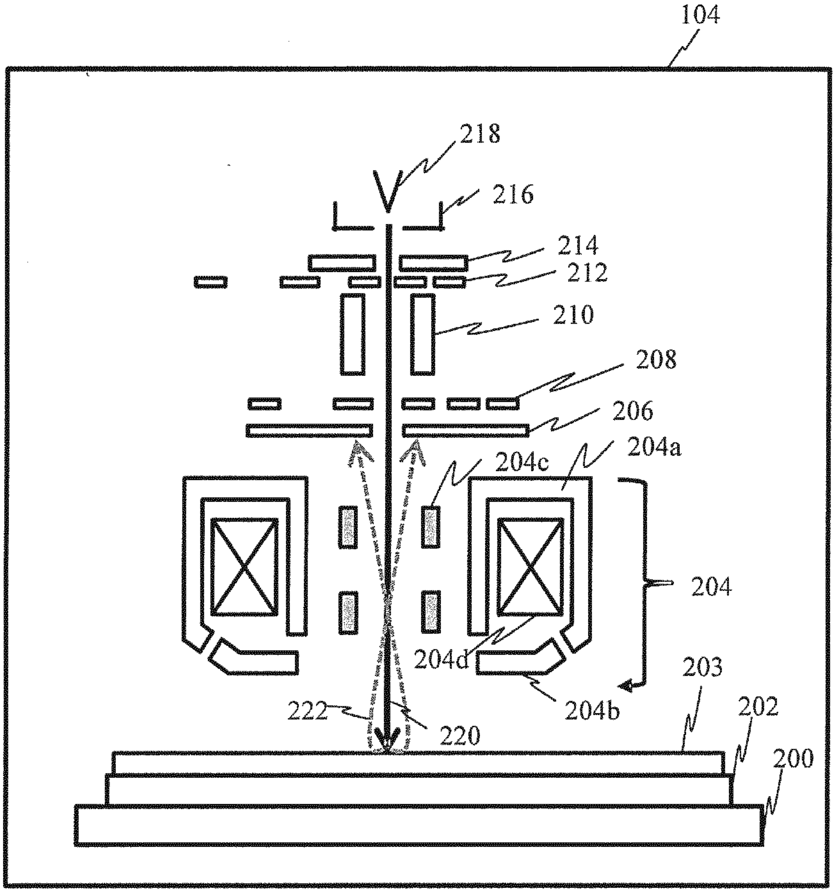

104
218
216
214
212
210
208
206
204c
204a
204
204d
204b
203
202
200
222
220

Fig. 2

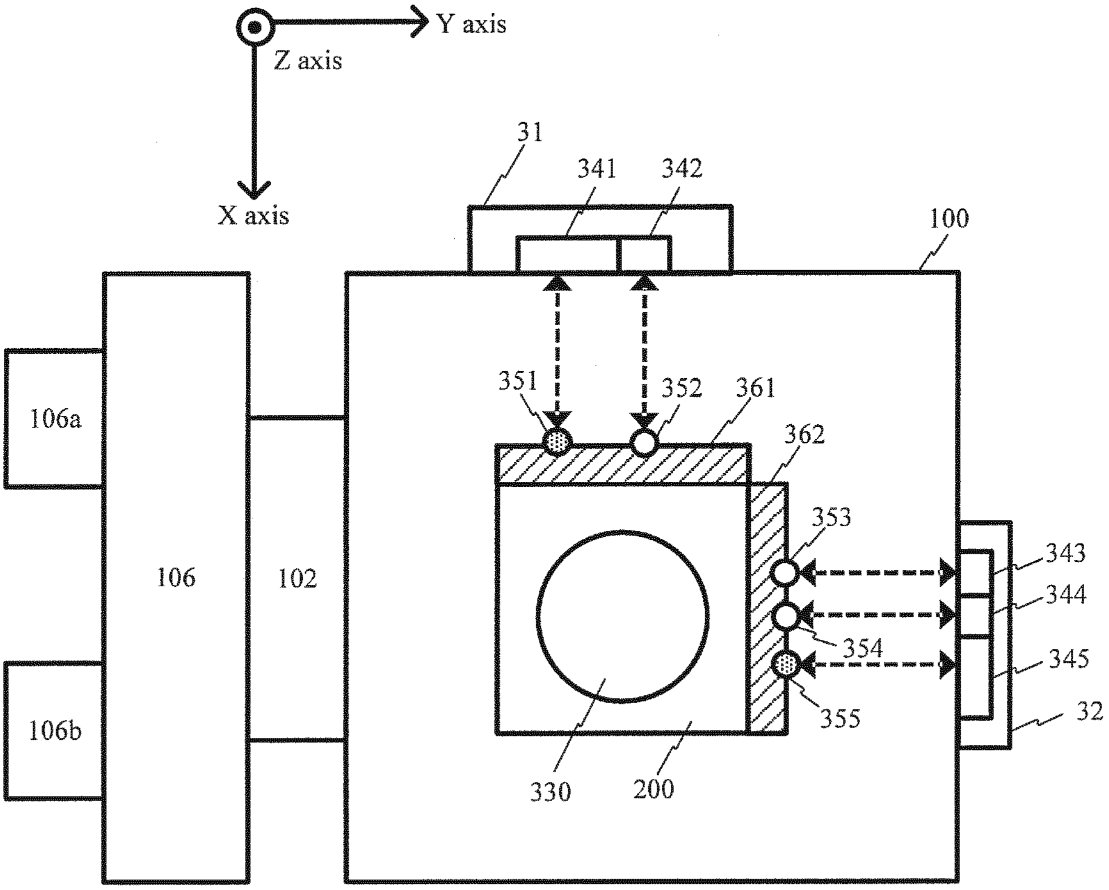


Fig. 3A

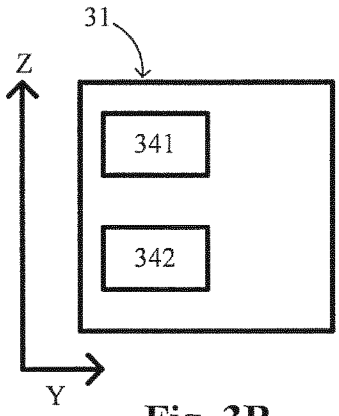


Fig. 3B

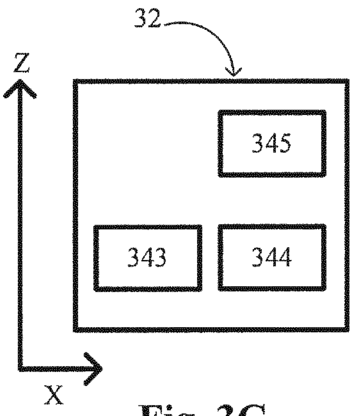


Fig. 3C

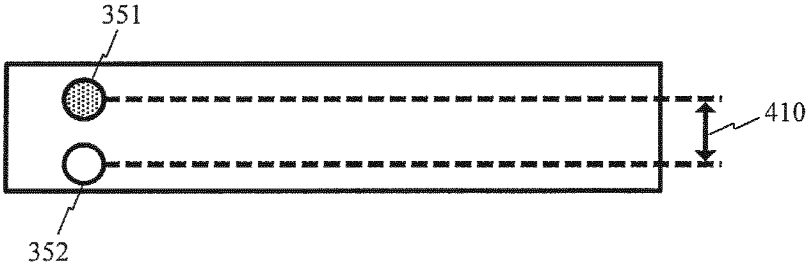


Fig. 4A

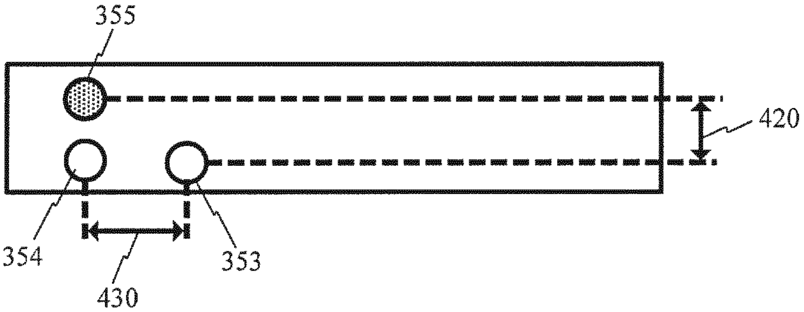
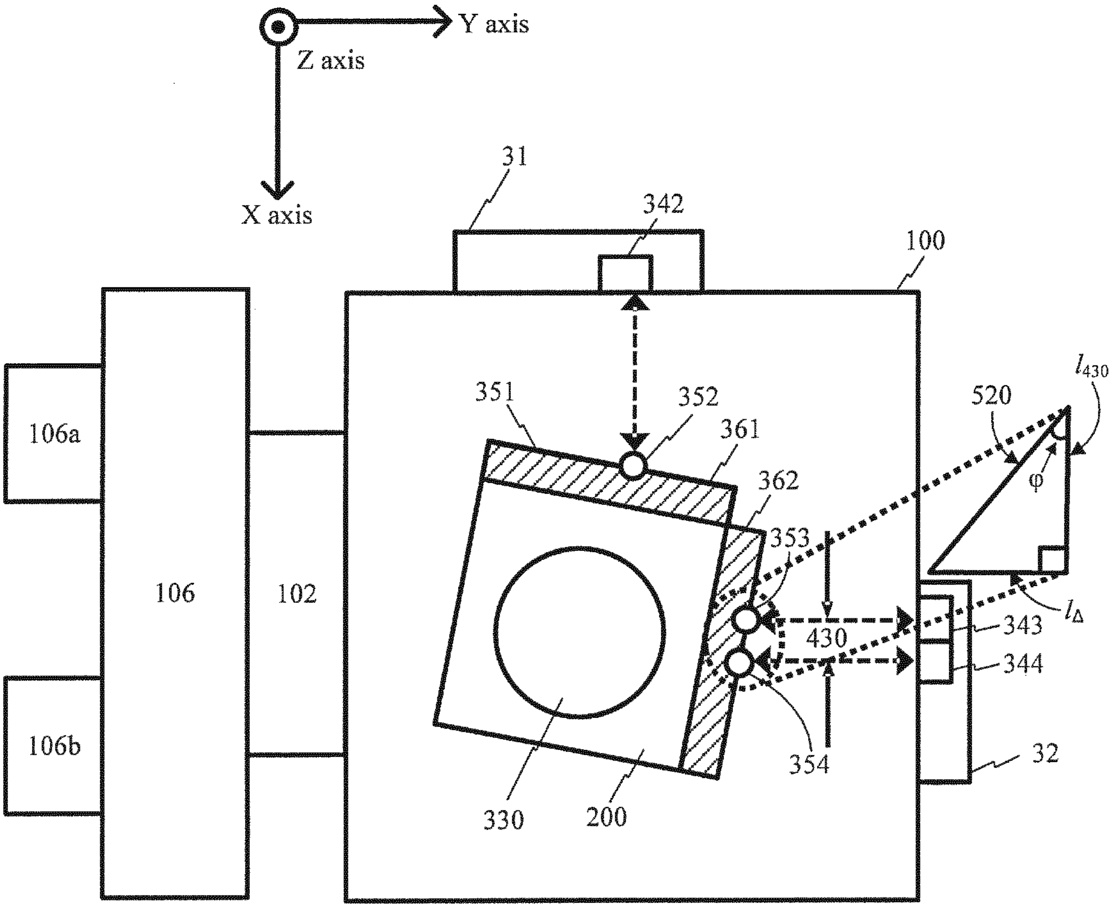


Fig. 4B


Y axis
Z axis
X axis
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342
100
106a
106
102
106b
351
352
361
362
353
430
354
330
200
520
l_{430}
φ
l_{Δ}
343
344
32

Fig. 5

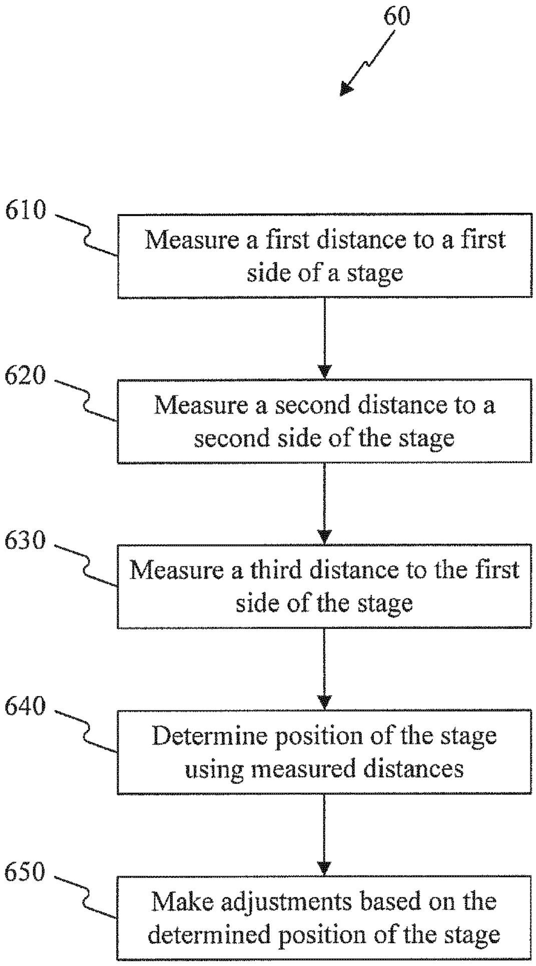
60
610
Measure a first distance to a first side of a stage
620
Measure a second distance to a second side of the stage
630
Measure a third distance to the first side of the stage
640
Determine position of the stage using measured distances
650
Make adjustments based on the determined position of the stage

Fig. 6

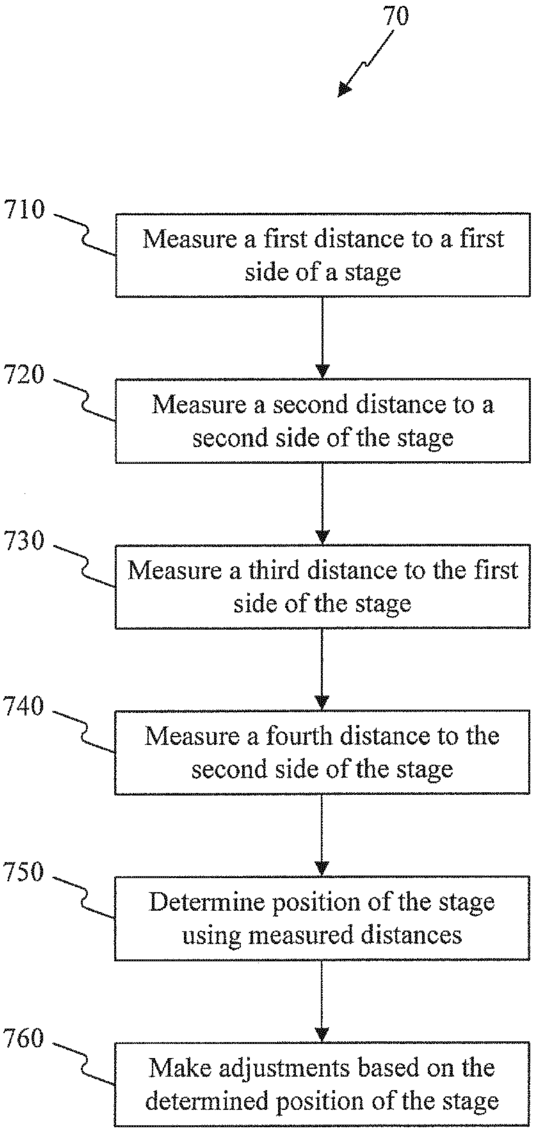
70
710
Measure a first distance to a first side of a stage
720
Measure a second distance to a second side of the stage
730
Measure a third distance to the first side of the stage
740
Measure a fourth distance to the second side of the stage
750
Determine position of the stage using measured distances
760
Make adjustments based on the determined position of the stage

Fig. 7

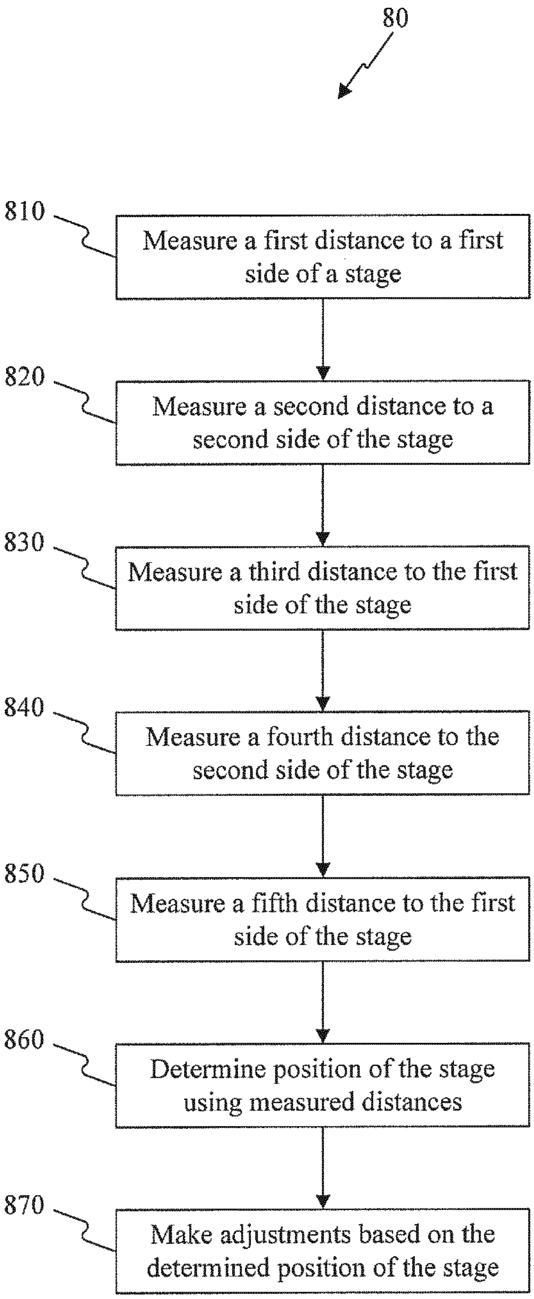
80
810
Measure a first distance to a first side of a stage
820
Measure a second distance to a second side of the stage
830
Measure a third distance to the first side of the stage
840
Measure a fourth distance to the second side of the stage
850
Measure a fifth distance to the first side of the stage
860
Determine position of the stage using measured distances
870
Make adjustments based on the determined position of the stage

Fig. 8

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2017/077155

A. CLASSIFICATION OF SUBJECT MATTER
INV. H01J37/20 G03F7/20
ADD.

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)
H01J G03F

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)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 7 897 942 B1 (BAREKET NOAH [US] ET AL) 1 March 2011 (2011-03-01) column 8, line 49 - column 9, line 16 -----	1-15
X	US 2009/273767 A1 (MAKINOUCHI SUSUMU [JP]) 5 November 2009 (2009-11-05) paragraph [0099] -----	1-4,14
X	US 2008/094592 A1 (SHIBAZAKI YUICHI [JP]) 24 April 2008 (2008-04-24) paragraphs [0192], [0194], [0197] -----	1,14
X	US 2008/094604 A1 (SHIBAZAKI YUICHI [JP]) 24 April 2008 (2008-04-24) paragraphs [0279], [0281], [0285] -----	1,14

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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"O" document referring to an oral disclosure, use, exhibition or other means

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"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

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"&" document member of the same patent family

Date of the actual completion of the international search 12 January 2018	Date of mailing of the international search report 23/01/2018
Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Authorized officer Oestreich, Sebastian

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