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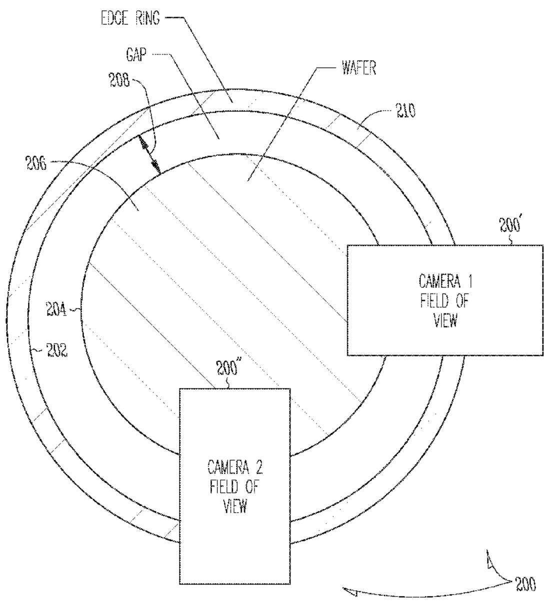

Fig.2

(57) Abstract: Systems and methods are provided for positioning a wafer in relation to a datum structure. In one example, a system comprises a camera arrangement including at least two cameras, each of the at least two cameras including a field of view when positioned in the camera arrangement, each field of view including a peripheral edge of the wafer and a peripheral edge of the datum structure. A processor receives positional data from each of the at least two cameras and determines, in relation to each field of view, a gap size between the respective peripheral edges of the wafer and the datum location included in the respective field of view. A controller adjusts a position of the wafer relative to the datum structure based on the determined respective gap sizes.

WO 2020/163644 A1

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SUBSTRATE LOCATION DETECTION AND ADJUSTMENT

CLAIM OF PRIORITY

[0001] This application claims the benefit of priority to United States Provisional Patent Application No. 62/802,932, to Martin et al, entitled "Wafer Location Detection and Adjustment" filed on February 8, 2019, which is incorporated by reference herein in its entirety.

FIELD

[0002] The present disclosure relates generally to substrate (for example a wafer) location detection and adjustment using camera images on process tools in semiconductor manufacturing. In some examples, a system and method for positioning a substrate relative to a datum structure such as an edge ring or chuck are provided.

BACKGROUND

[0003] The background description provided here is for the purpose of generally presenting the context of the disclosure. Work of the presently named inventors, to the extent it is described in this background section, as well as aspects of the description that may not otherwise qualify as prior art at the time of filing, are neither expressly nor impliedly admitted as prior art against the present disclosure.

[0004] One method of centering a wafer to an edge ring or electrostatic chuck (ESC) relies on obtaining blanket etch rate and backside particle data with the wafer placed in a "best-guess" wafer center location. The blanket etch rates are obtained with the wafer at this location, and post-etch metrology is then performed on the blanket wafers to determine their deviation from center. A backside particle test uses backside particle imprints of a precoat on the ESC to decide wafer offset relative to the ESC. This information can be used to adjust a vacuum transfer module (VTM) robot calibration and achieve wafer centering. This process is expensive at least for the reason that blanket wafers are costly, and cumbersome.

SUMMARY

[0005] In some examples, a system for positioning a wafer relative to a datum structure is provided. An example system comprises a camera arrangement including at least two cameras, each of the at least two cameras including a field of view when positioned in the camera arrangement, each field of view including a peripheral edge of the wafer and a peripheral edge of the datum structure; a processor to receive positional data from each of the at least two cameras and determine, in relation to each field of view, a gap size between the respective peripheral edges of the wafer and the datum location included in the respective field of view; and a controller to adjust a position of the wafer relative to the datum structure based on the determined respective gap sizes.

[0006] In some examples, the datum location includes an edge ring. In some examples, the datum location includes a chuck.

[0007] In some examples, the camera arrangement is provided in a wall of a wafer processing chamber.

[0008] In some examples, the camera arrangement includes a third camera, the third camera providing positional data in relation to a respective third field of view, to the processor.

[0009] In some examples, the determined respective gap sizes are compared against respective predetermined gap sizes, the respective predetermined gap sizes associated with a centered or desired position of the wafer in relation to the datum structure.

[0010] In some examples, the controller includes a robotic arm of a vacuum transfer module (VTM).

[0011] In some examples, the processor identifies a center of the wafer based on the determined respective gap sizes.

[0012] In some examples, a system for positioning a wafer relative to a datum structure comprises a camera arrangement including one or more cameras, each of the one or more cameras including a field of view when positioned in the camera arrangement, each field of view including a peripheral edge of the wafer and a peripheral edge of the datum structure; a processor to receive positional data from the or each camera and determine, in relation to each field of view, a gap size between the respective peripheral edges of the wafer and the datum location included in the respective field of view; and a

controller to adjust a position of the wafer relative to the datum structure based on the determined respective gap sizes.

[0013] In some examples, the one or more cameras includes a single movable camera.

[0014] In some examples, the single movable camera is mounted on a robotic arm.

[0015] In some examples, the robotic arm is mounted on a vacuum transfer module (VTM).

[0016] In some examples, the camera arrangement is provided in a wall of a wafer processing chamber.

DESCRIPTION OF THE DRAWINGS

[0017] Some embodiments are illustrated by way of example and not limitation in the figures of the accompanying drawings:

[0018] **FIG. 1** is a schematic diagram of a reaction chamber within which some examples of the methods of the present disclosure may be employed, according to some examples.

[0019] **FIGS. 2-3** depict camera arrangements, according to some examples.

[0020] **FIGS. 4-8** depict camera images, according to some examples.

[0021] **FIG. 9** depicts a camera arrangement, according to an example embodiment.

[0022] **FIG. 10** depicts a scatter plot, according to an example.

[0023] **FIG. 11** depicts operations in a method of centering a wafer, according to an example.

[0024] **FIG. 12** depicts a single camera arrangement, according to an example.

DESCRIPTION

[0025] The description that follows includes systems, methods, and techniques that embody illustrative embodiments of the present invention. In the following description, for purposes of explanation, numerous specific details are set forth in order to provide a thorough understanding of example embodiments.

It will be evident, however, to one skilled in the art, that the present inventive subject matter may be practiced without these specific details.

[0026] A portion of the disclosure of this patent document contains material that is subject to copyright protection. The copyright owner has no objection to the facsimile reproduction by anyone of the patent document or the patent disclosure, as it appears in the Patent and Trademark Office patent files or records, but otherwise reserves all copyright rights whatsoever. The following notice applies to the software and data as described below and in the drawings that form a part of this document: Lam Research Corporation 2018-2020, All Rights Reserved. The term "wafer" as used herein as example is intended to include within its ambit a "substrate" more generally. A substrate may include a photomask, a flat-panel display, and so forth that may also processed with the systems and methods described herein.

[0027] An example chamber in which some examples of the present disclosure may be employed, with appropriate chamber modifications for film deposition and control testing, is shown in **FIG.1** of the accompanying drawings. A typical plasma etching (or deposition) apparatus comprises a reactor in which there is a chamber through which reactive gas or gases flow. Within the chamber, the gases are ionized into a plasma, typically by radio frequency energy. The highly reactive ions of the plasma gas are able to react with material, such as a polymer mask on a surface of a semi-conductor wafer being processed into integrated circuits (IC's). Prior to etching, the wafer is placed in the chamber and held in proper position by a chuck or holder which exposes a top surface of the wafer to the plasma gas. There are several types of chucks known in the art. The chuck provides an isothermal surface and serves as a heat sink for the wafer. In one type, a semiconductor wafer is held in place for etching by mechanical clamping means. In another type of chuck, a semiconductor wafer is held in place by electrostatic force generated by an electric field between the chuck and wafer. The present methods are applicable to both types of chucks.

[0028] **FIG. 1** illustrates a capacitively-coupled plasma processing chamber 100, representing an exemplary plasma processing chamber of the types typically employed to etch a substrate. Referring now to **FIG. 1**, a chuck 102, representing the workpiece holder on which a substrate, such as a wafer

104, is positioned during etching. The chuck 102 may be implemented by any suitable chucking technique, e.g., electrostatic, mechanical, clamping, vacuum, or the like. During etching, the chuck 102 is typically supplied with dual RF frequencies (a low frequency and high frequency), for example 2 MHz and 27 MHz, simultaneously, during etching by a dual frequency source 106.

[0029] A vacuum transfer module (VTM) (not shown) may be used to place and center (or position) the wafer 104 on the chuck 102. Accurate wafer positioning or centering is typically a key aspect when seeking to perform successfully certain processing operations on the wafer 104 within the processing chamber 100. These operations may include deposition, etch, and edge bevel removal (EBR), for example. Other operations are possible. In some examples, a VTM includes one or more robotic controls or arms to manipulate the wafer 104 as it is placed on the chuck 102. In examples of the present disclosure, a VTM robotic arm is guided during wafer placement and centering by feedback or other data generated by an array of cameras and a VTM control module discussed further below. One or more components of the processing chamber 100 may be used as a datum point in determining a position or center of the wafer 104. In some examples, a proximity of one or more sites at the peripheral edge of the wafer 104 to a processing chamber component is used in determining a wafer center. Two or three peripheral edge sites of the wafer 104 may be used in some examples. In some examples, a datum component includes an edge ring 118.

[0030] Referring again to **FIG. 1**, an upper electrode 108 is located above the wafer 104. The upper electrode 108 is grounded. **FIG. 1** illustrates an etching reactor where the surface of the upper electrode 108 is larger than the surface of the chuck 102 and the wafer 104. During etching, plasma 110 is formed from etchant source gas supplied via a gas line 112 and pumped out through an exhaust line 114. An electrical insulator ring 109 insulates the upper electrode 108 from the processing chamber 100.

[0031] Confinement rings 116 may be placed between the upper electrode 108 and a bottom electrode, such as the chuck 102 in **FIG. 1**. In general, confinement rings 116 help confine the etching plasma 110 to the region above the wafer 104 to improve process control and to ensure repeatability.

[0032] When RF power is supplied to chuck 102 from dual frequency source 106, equipotential field lines are set up over wafer 104. The equipotential field lines are the electric field lines across the plasma sheath that is between wafer 104 and the plasma 110. In some examples, the equipotential surfaces and electric field lines are normal to each other. There are equipotential surfaces between the wafer 104 and the plasma 110. The electric field lines accelerate charged particles across these equipotential surfaces. During plasma processing, the positive ions accelerate across the equipotential field lines to impinge on the surface of wafer 104, thereby providing the desired etch effect, such as improving etch directionality. Due to the geometry of the upper electrode 108 and the chuck 102, the field lines may not be uniform across the wafer surface and may vary significantly at the edge of the wafer 104. Accordingly, an edge (or focus) ring 118 is typically provided to improve process uniformity across the entire wafer surface. With reference to **FIG. 1**, the wafer 104 is shown disposed within an edge ring 118, which may be formed of a suitable dielectric material such as ceramic, quartz, plastic, or the like. Thus, the presence of the edge ring 118 allows the equipotential field lines to be disposed substantially uniformly over the entire surface of the wafer 104.

[0033] An electrically conductive shield 120 substantially encircles the edge ring 118. The electrically conductive shield 120 is configured to be substantially grounded within the processing chamber 100. The electrically conductive shield 120 prevents the presence of unwanted equipotential field lines outside of the edge ring 118.

[0034] As discussed above, there may be significant challenges associated with the use of blanket wafers in wafer centering operations. Examples of the present disclosure do not require blanket wafer images and instead use images captured by cameras mounted above a wafer 104 to measure and guide wafer centering operations. Wafer centering operations may be conducted relative to a datum structure or component within the process module, such as the edge ring 118 or the chuck 102, such as an electrostatic chuck (ESC). In some examples, positional data is transmitted as feedback to a wafer transferring module (for example, a VTM) to adjust its calibration until the wafer 104 is appropriately centered on the chuck 102.

[0035] An example of the present disclosure performs an in-situ measurement of the wafer 104 during wafer centering operations and provides immediate feedback to a controller user interface (UI) of a control module. With a wafer 104 placed on the chuck 102 in the processing chamber 100, an array of one or more measurement cameras takes an image that may include one or more sites or portions at the outer peripheral edge of the wafer 104, and at least one inner edge of the edge ring 118. Image processing software locates the wafer periphery and inner edge of the edge ring 118 and calculates a separation distance, or gap, between them. In some examples, this measurement is performed at several points around the periphery of the wafer 104. Measurement results are then used to adjust the VTM robotic controls for placing the wafer 104 on the chuck 102 in the processing chamber 100. Checking the progress of the wafer centering operations can be performed quickly by repeating the above procedure.

[0036] With reference to **FIG. 2**, an arrangement 200 of one or more cameras (for example, camera 1 and camera 2) associated with a processing chamber 100 can capture images and make image measurements. In some examples, each of the cameras 1 and 2 has a respective field of view 200' and 200" that can detect an inner edge 202 of an edge ring 210 and the peripheral edge 204 of a wafer 206. A separation distance or gap 208 between the inner edge 202 of the edge ring 210 and the peripheral edge 204 can be detected and measured by the cameras 1 and 2. A convenient example arrangement for performing the gap 208 measurement includes providing a vacuum-seal window within a wall of the processing chamber 100 and locating the cameras 1 and 2 in the window. In some examples, image capture and gap measurement are performed during startup and maintenance phases of the processing chamber 100. In other examples, the cameras 1 and 2 are mounted onto a robotic arm of a vacuum transfer module (VTM) to facilitate centering and gap measurements being taken under control of an operator of the processing chamber 100. In some examples, lighting is controlled during gap image measurements.

[0037] Although the arrangement 200 in **FIG. 2** includes two cameras, other arrangements are possible. For example, a single, moveable camera may be arranged in two different positions to obtain respective fields of view 200' and 200". In yet another example arrangement 1200 shown in **FIG. 12**, a single movable camera can be moved between positions 1202, 1204, and 1206 to obtain or generate one or more respective fields of view 1200', 1200" and 1200"' at those camera positions. Some or all the cameras in the various examples described herein may be fixed or movable. Some examples may include or generate a composite field of view, for example a single view taken by a single camera that includes or encompasses a plurality of sub-views. Example sub-views may include those at positions 1202, 1204, and 1206 in **FIG. 12**. Other combinations of fields of view and camera arrangements are possible.

[0038] An alternate camera arrangement 300 is shown in **FIG. 3**. The illustrated arrangement includes three cameras 1, 2, and 3 (labeled 302, 304, and 306 in the view) positioned to look down on and take images of an edge ring 310 and wafer 312 disposed within a processing chamber, such as a processing chamber 100 of **FIG. 1**. Each camera 1, 2, and 3 has a respective field of view 300', 300", and 300"'. A VTM 308 (not shown to scale) may be located adjacent the monitored processing chamber 100. In some examples, a single VTM 308 has a rectangular footprint that spans an area large enough to service a plurality of adjacent processing chambers 100. In some examples, a single VTM 308 has five processing chamber 100 positioned along each side of it. The VTM 308 (**FIG. 3**) may include a robotic arm 310 (not shown to scale) for manipulating one or more cameras between respective fields of view 302, 304, and 306. A single camera or several cameras may be mounted on the VTM arm 310 so that a field of view or gap measurement can be established or taken at the discretion of an operator, or by a processor under automation. In some examples, illumination of the fields of view is controlled, for example during a taking of a gap measurement or when monitoring a field of view. Although the arrangement in **FIG. 3** includes three cameras 1-3, a single moving camera or several stationary cameras may be used to take such measurements.

[0039] **FIG. 4** shows pictorial example images 402 and 404 captured by the cameras 1 and 2 of the various embodiments described herein. The image 402 on the left depicts a relatively small gap 406 between an inner edge 202 of an edge ring 210 and a peripheral edge 204 of a wafer 206. The camera 1 has thus detected that the wafer placement is relatively close to the edge ring 210. The image 404 on the right depicts a larger gap 408 between the inner edge 202 of the edge ring 210 and the peripheral edge 204 of the wafer 206. Camera 2 has detected that the wafer placement is further away from the edge ring 210. A wafer-to-edge ring gap 208 in **FIG. 2** (or 406 and 408 in **FIG. 4**) may be adjusted or set based on different VTM robot settings, in some examples. A bare silicon (Si) wafer 206 (for example) may be employed, but other types of wafer 206 are possible. Other examples may include use of a calibration wafer carrying markings indicating a reference angle and/or wafer radius and, in some examples, may be provided in a differentiating color within the images 402 and 404. Information regarding the gaps 406 and 408 (positional data) may be transmitted dynamically as feedback to the VTM 308 during wafer centering operations. Based on the feedback received, a wafer position may be adjusted incrementally or continuously until preset or predetermined gap values for a wafer-central position are established.

[0040] **FIGS 5-8** show respective example images (for example in fields of view 300', 300'', and 300''' taken by cameras 1, 2 and 3 in **FIG. 3**) of peripheral edges 204 of a wafer 502 corresponding to the location of each camera next to an associated inner edge 202 of an edge ring 210. The wafer 502 is positioned on a chuck 102 within a processing chamber 100. Although the peripheral edges of the wafer 502 are represented by linear lines, it will be appreciated that in real-life they will be slightly arcuate. A location of a VTM 512 adjacent the processing chamber 100 is shown in **FIG. 5**. The VTM 512 is positioned similarly in each of the views of **FIGS. 6-8**. In the view 500 of **FIG. 5**, initial or datum locations 504, 506, and 508 of a top edge, bottom edge, and right-side edge of the wafer 502 are indicated respectively in **FIG. 5**. A separation distance or top gap 510 (for purposes of this example) may be derived and noted accordingly.

[0041] The images in **FIG. 6** are representative of a wafer movement in the direction 602 under control of a robotic arm of the VTM 512 away from the VTM 512 location (**FIG. 5**). The top gap 510 has widened accordingly.

[0042] The images in **FIG. 7** are representative of wafer movement in the 702 towards the VTM 512 back to the initial or datum wafer locations. The size of top gap 510 has been restored accordingly.

[0043] For further purposes of this example, an initial side gap 704 (**FIG. 7**) may be derived and noted. The images in **FIG. 8** are representative of wafer movement under control of a robotic arm of the VTM 512 in the direction

802 to the right. The side gap 704 has narrowed accordingly. Positional data representative of such wafer movement, derived from top and side gap images captured by the array of cameras 1, 2, and 3, are dynamically transmitted back to a control module of the VTM 512 to facilitate the location and centering of a wafer 502 during a wafer placement and centering operation.

[0044] With reference to **FIG. 9**, an arrangement 900 of a wafer 206 and edge ring 210 is shown. Using the edge ring 210 as a datum, a center of a wafer 206 of known diameter (and hence known radius) may be determined based on measurements of a top gap 510 and a side gap 704 or based on locations associated with gaps 510 and 704. Based on images taken by cameras 1 and 2 shown in the view, the separation distance or top gap 510 between a location X on a peripheral edge 204 of the wafer 206, and an adjacent location X' on the inner edge 202 of an edge ring 210, may be determined. A separation distance or side gap 704 may be determined in a similar manner for locations Y and Y'. For simplicity, the cameras 1 and 2 are not shown at the true locations in the top and left quadrants where images of top gap 510 and side gap 704 would be taken in real-life, but rather at camera locations in the right and bottom quadrants, as illustrated.

[0045] In some examples, the locations of points X' and Y' are known or can be derived, for example, based on a known location or dimensions of the edge ring 210 which can serve as a datum component in this regard. A center 908 of the edge ring 210 can be established accordingly as a reference for wafer centering and processing purposes.

[0046] Using the known locations of points X' and Y', the top and side gaps 510 and 704 may be applied respectively to determine the location of points X and Y on the peripheral edge 204 of the wafer 206. The radius of the wafer 206 is known and a notional circumference (or an arc portion of a circumference), based on the wafer radius, can be circumscribed around each point X and Y accordingly. The notional circumference for point X is labeled 902, and 904 for point Y, respectively. An intersection of the notional circumferences 902 and 904 within the periphery of the wafer 206 establishes a center of the wafer 206 at center 910. An intersection of the circumferences 902 and 904 (at point 906) outside the periphery of the wafer 206 may be discarded as an invalid result as it will be appreciated that a center of a wafer 206 will fall within its periphery. The determined center 910 of the wafer 206 may be compared on a dynamic basis against the true center 908 of the edge ring 210 to derive offset or positional data 912.

[0047] In some examples, feedback based on the offset data is provided to the control module of the VTM 512 to adjust a position or path of a wafer 206 during wafer centering. During wafer centering operations, positional adjustments for a wafer 206 may be made by a control module of a VTM 512 based on determinations of the top and side gaps 510 and 704, or locations of the edge ring 210 and wafer centers 908 and 910 or based on a combination of both sets of data or portions thereof.

[0048] **FIG. 10** depicts a scatter plot 1000 showing a measured change in a wafer center obtained with camera measurements (solid ring dots 1002) and VTM robot setpoint commands (dashed ring dots 1004). Line segments 1006 and 1008 link a measured wafer center 1002 to its associated robot setpoint 1004. Relatively shorter line segments 1008, shown in solid outline, are indicative that the respective measured wafer center 1002 is within specification of the VTM robot wafer setpoint 1004. This is reflective of the robot repeatability specification mentioned above. Relatively longer line segments 1006are indicative that the measured wafer center 1002 is within, for example, 133% of the VTM robot spec. Other margins of accuracy may be used. The hashed line 1010 indicates for example a single wafer measurement in excess of 133% of the robot setpoint. The dotted line 1012 indicates for example that a camera measurement that correctly caught an error in the robot placement. Other indicators are possible.

[0049] Thus, in some examples, methods for centering a wafer are provided. With reference to **FIG. 11**, a method 1100 for centering a wafer relative to a datum structure comprises, at operation 1102, placing, adjacent a wafer processing chamber, a camera arrangement including at least two cameras, each of the at least two cameras including a field of view when positioned in the camera arrangement, each field of view including a peripheral edge of the wafer and a peripheral edge of the datum structure; at 1104, receiving positional data from each of the at least two cameras and determining, in relation to each field of view, a gap size between the respective peripheral edges of the wafer and the datum location included in the respective field of view; and, at 1106, adjusting a position of the wafer relative to the datum structure based on the determined respective gap sizes.

[0050] In some examples, the datum location includes an edge ring. In some examples, the datum location includes a chuck.

[0051] In some examples, the method 1100 further comprises providing the camera arrangement in a wall of the wafer processing chamber.

[0052] In some examples, the method 1100 further comprises including a third camera in the camera arrangement, and providing positional data from the third camera, in relation to a respective third field of view, to the processor.

[0053] In some examples, the method 1100 further comprises comparing the determined respective gap sizes against respective predetermined gap sizes, the respective predetermined gap sizes associated with a centered or desired position of the wafer in relation to the datum structure or the wafer processing chamber.

[0054] In some examples, the method 1100 further comprising including, in the controller, a robotic arm of a vacuum transfer module (VTM).

[0055] Thus, embodiments are provided for camera-based image sensing to position a wafer location relative to an edge ring 210 inside a processing chamber 100. Examples of the present disclosure may provide improved speed, cost and accuracy. Some examples may facilitate making quick in situ measurements during wafer positioning or centering operations. Normally blanket wafers are etched in the process module and metrology is performed on the wafers 206 to determine the wafer centering. In a fab, where wafers 206 are typically tracked, premeasured, and moved, conventional measurement operations may take a given period to complete. Present processes, on the other hand, may reduce that time by a factor of eight. On a lab process tool, using methods disclosed herein, performing these operations may take only 12.5% of the conventional time necessary in a fab.

[0056] Conventional methods of wafer centering typically take a long time to complete, and often employ blanket wafers. Some example methods herein incur only a one-time cost. Camera measurements of the present disclosure can determine a wafer placement in most cases to within specification of a VTM robot control setpoint, in some examples. In all but one example of **FIG. 10**, the camera measurements determined a wafer placement to within specification of conventional backside particle metrology. Embodiments may be configured or adjusted as needed by making changes in both hardware and image processing algorithms.

[0057] Although an embodiment has been described with reference to specific example embodiments, it will be evident that various modifications and changes may be made to these embodiments without departing from the broader scope of the embodiments. Accordingly, the specification and drawings are to be regarded in an illustrative rather than a restrictive sense. The accompanying drawings that form a part hereof show, by way of illustration, and not of limitation, specific embodiments in which the subject matter may be practiced. The embodiments illustrated are described in sufficient detail to enable those skilled in the art to practice the teachings disclosed herein. Other embodiments may be utilized and derived therefrom, such that structural and logical substitutions and changes may be made without departing from the scope of this disclosure. This Detailed Description, therefore, is not to be taken in a limiting sense, and the scope of various embodiments is defined only by the appended claims, along with the full range of equivalents to which such claims are entitled.

[0058] Such embodiments of the inventive subject matter may be referred to herein, individually and/or collectively, by the term "invention" merely for convenience and without intending to voluntarily limit the scope of this application to any single invention or inventive concept if more than one is in fact disclosed. Thus, although specific embodiments have been illustrated and described herein, it should be appreciated that any arrangement calculated to achieve the same purpose may be substituted for the specific embodiments shown. This disclosure is intended to cover any and all adaptations or variations of various embodiments. Combinations of the above embodiments, and other embodiments not specifically described herein, will be apparent to those of skill in the art upon reviewing the above description.

CLAIMS

1. A system for positioning a wafer relative to a datum structure, the system comprising:

a camera arrangement including at least two cameras, each of the at least two cameras including a field of view when positioned in the camera arrangement, each field of view including a peripheral edge of the wafer and a peripheral edge of the datum structure;

a processor to receive positional data from each of the at least two cameras and determine, in relation to each field of view, a gap size between the respective peripheral edges of the wafer and the datum location included in the respective field of view; and

a controller to adjust a position of the wafer relative to the datum structure based on the determined respective gap sizes.

2. The system of claim 1, wherein the datum location includes an edge ring.

3. The system of claim 1, wherein the datum location includes a chuck.

4. The system of claim 1, wherein the camera arrangement is provided in a wall of a wafer processing chamber.

5. The system of claim 1, wherein the camera arrangement includes a third camera, the third camera providing positional data in relation to a respective third field of view, to the processor.

6. The system of claim 1, wherein the determined respective gap sizes are compared against respective predetermined gap sizes, the respective predetermined gap sizes associated with a centered or desired position of the wafer in relation to the datum structure.

7. The system of claim 1, wherein the controller includes a robotic arm of a vacuum transfer module (VTM).

8. The system of claim 1, wherein the processor identifies a center of the wafer based on the determined respective gap sizes.

9. A method for positioning a wafer relative to a datum structure, the method comprising:

placing, adjacent a wafer processing chamber, a camera arrangement including at least two cameras, each of the at least two cameras including a field of view when positioned in the camera arrangement, each field of view including a peripheral edge of the wafer and a peripheral edge of the datum structure;

receiving positional data from each of the at least two cameras and determining, in relation to each field of view, a gap size between the respective peripheral edges of the wafer and the datum location included in the respective field of view; and

adjusting a position of the wafer relative to the datum structure based on the determined respective gap sizes.

10. The method of claim 9, wherein the datum location includes an edge ring.

11. The method of claim 9, wherein the datum location includes a chuck.

12. The method of claim 9, further comprising providing the camera arrangement in a wall of the wafer processing chamber.

13. The method of claim 9, further comprising including a third camera in the camera arrangement, and providing positional data from the third camera, in relation to a respective third field of view, to the processor.

14. The method of claim 9, further comprising comparing the determined respective gap sizes against respective predetermined gap sizes, the respective predetermined gap sizes associated with a centered or desired position of the wafer in relation to the datum structure or the wafer processing chamber.

15. The method of claim 9, further comprising including, in the controller, a robotic arm of a vacuum transfer module (VTM).

16. A system for positioning a wafer relative to a datum structure, the system comprising:

a camera arrangement including one or more cameras, each of the one or more cameras including a field of view when positioned in the camera arrangement, each field of view including a peripheral edge of the wafer and a peripheral edge of the datum structure;

a processor to receive positional data from the or each camera and determine, in relation to each field of view, a gap size between the respective peripheral edges of the wafer and the datum location included in the respective field of view; and

a controller to adjust a position of the wafer relative to the datum structure based on the determined respective gap sizes.

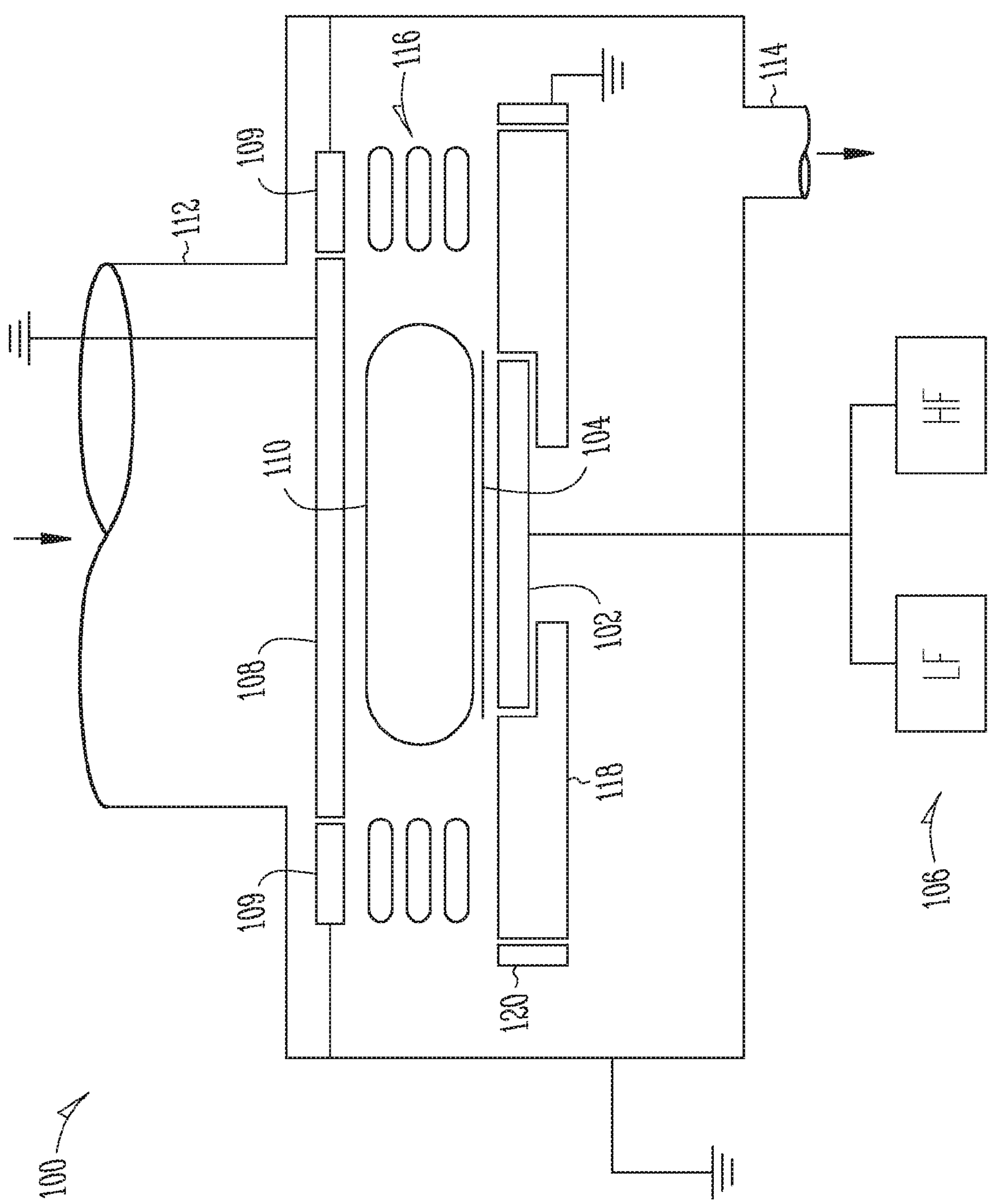
17. The system of claim 16, wherein the one or more cameras includes a single movable camera.

18. The system of claim 17, wherein the single movable camera is mounted on a robotic arm.

19. The system of claim 18, wherein the robotic arm is mounted on a vacuum transfer module (VTM).

20. The system of claim 16, wherein the camera arrangement is provided in a wall of a wafer processing chamber.

Fig. 1



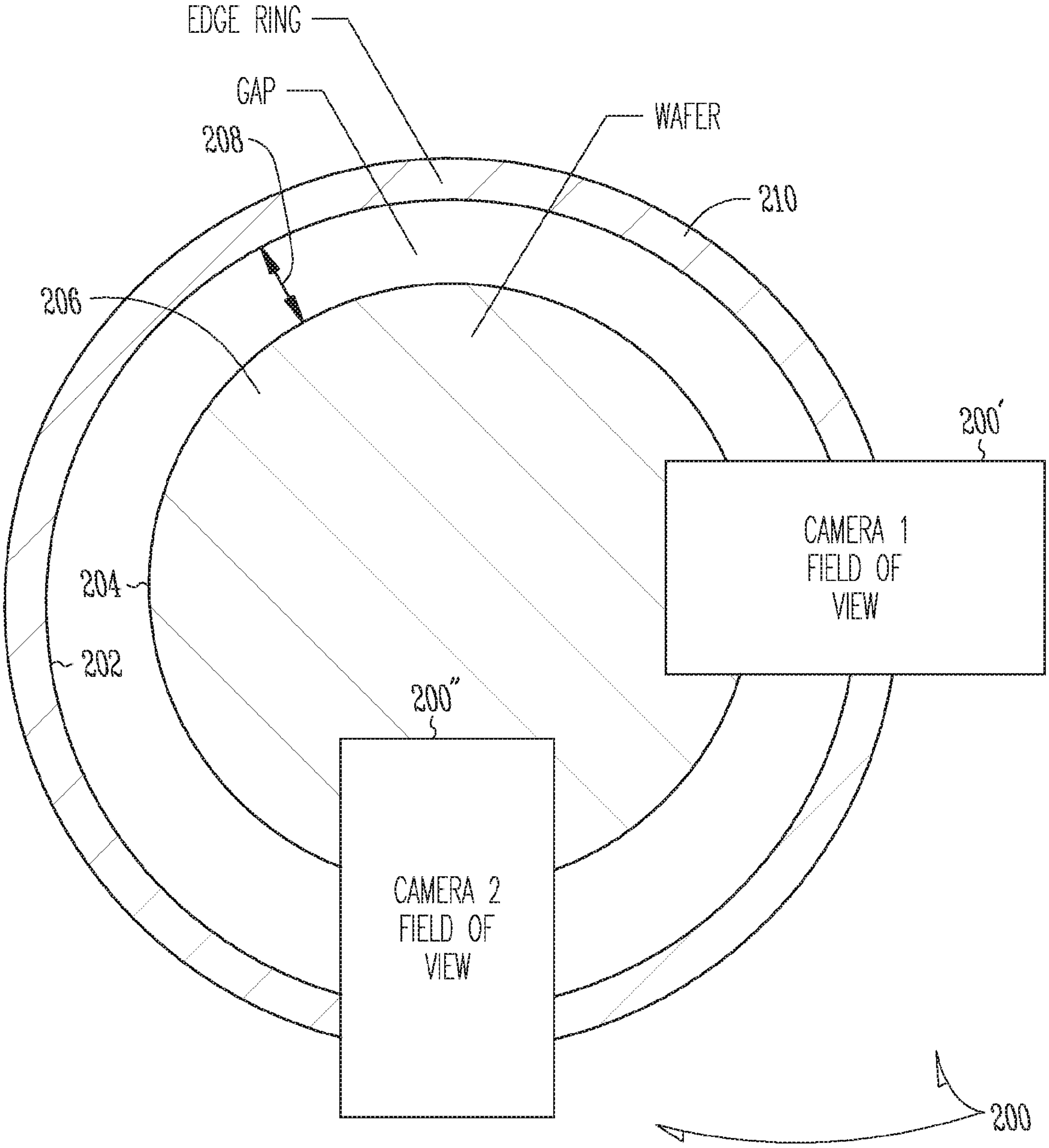

EDGE RING
GAP
WAFER
208
210
206
200′
CAMERA 1 FIELD OF VIEW
204
202
200″
CAMERA 2 FIELD OF VIEW
200

Fig.2

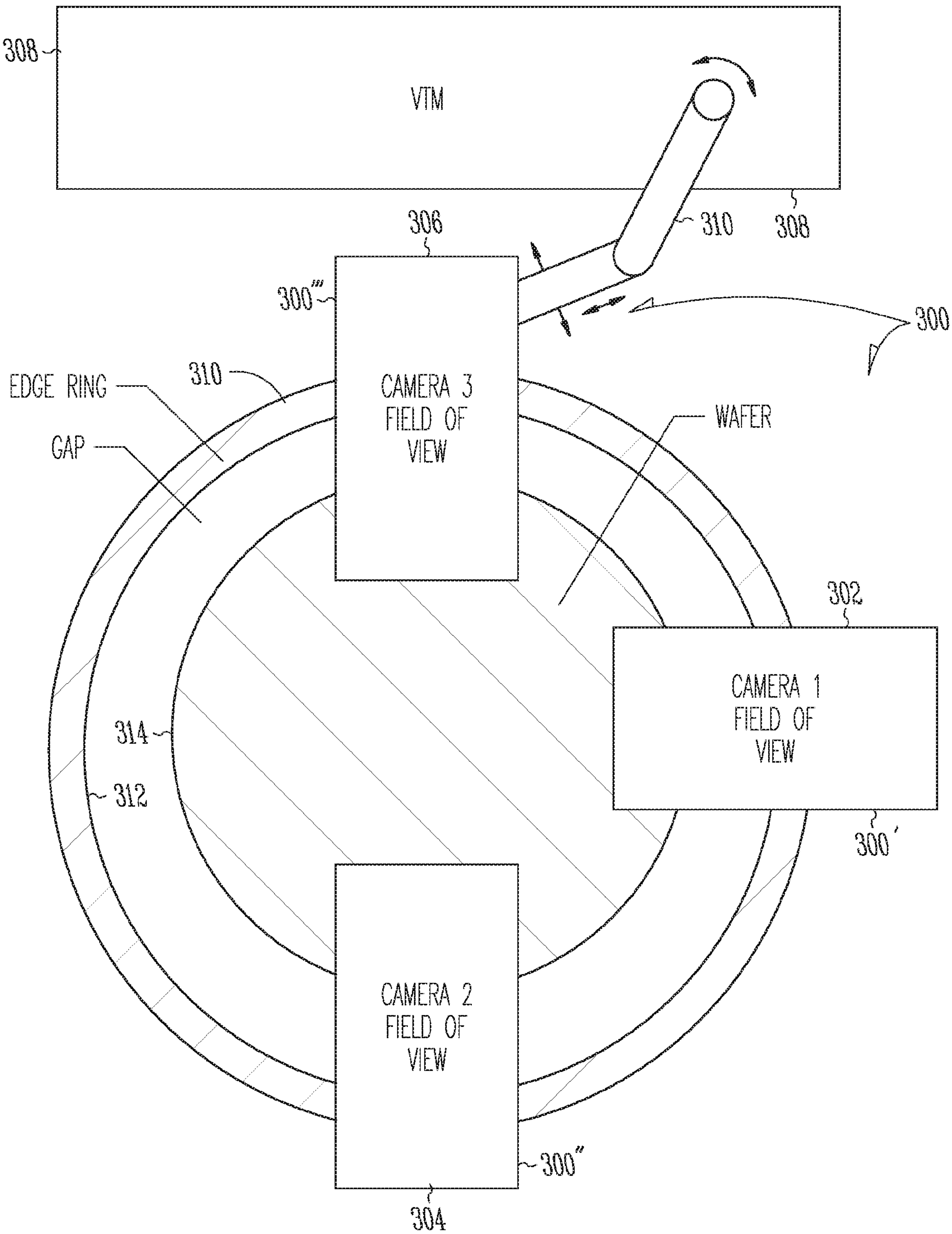

308
VTM
310
308
306
300'''
300
CAMERA 3
FIELD OF
VIEW
EDGE RING
310
WAFER
GAP
302
CAMERA 1
FIELD OF
VIEW
314
312
300'
CAMERA 2
FIELD OF
VIEW
300''
304

Fig.3

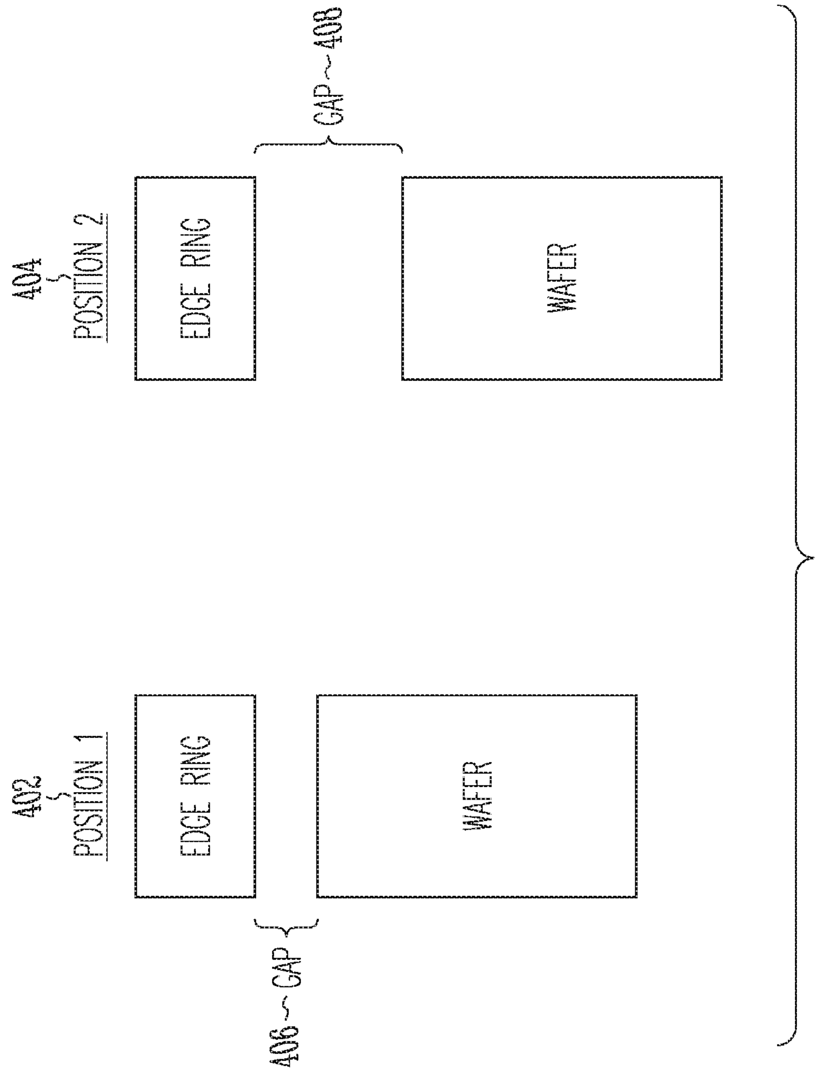

402
POSITION 1
EDGE RING
WAFER
406~GAP
404
POSITION 2
EDGE RING
WAFER
GAP~408

Fig. 4

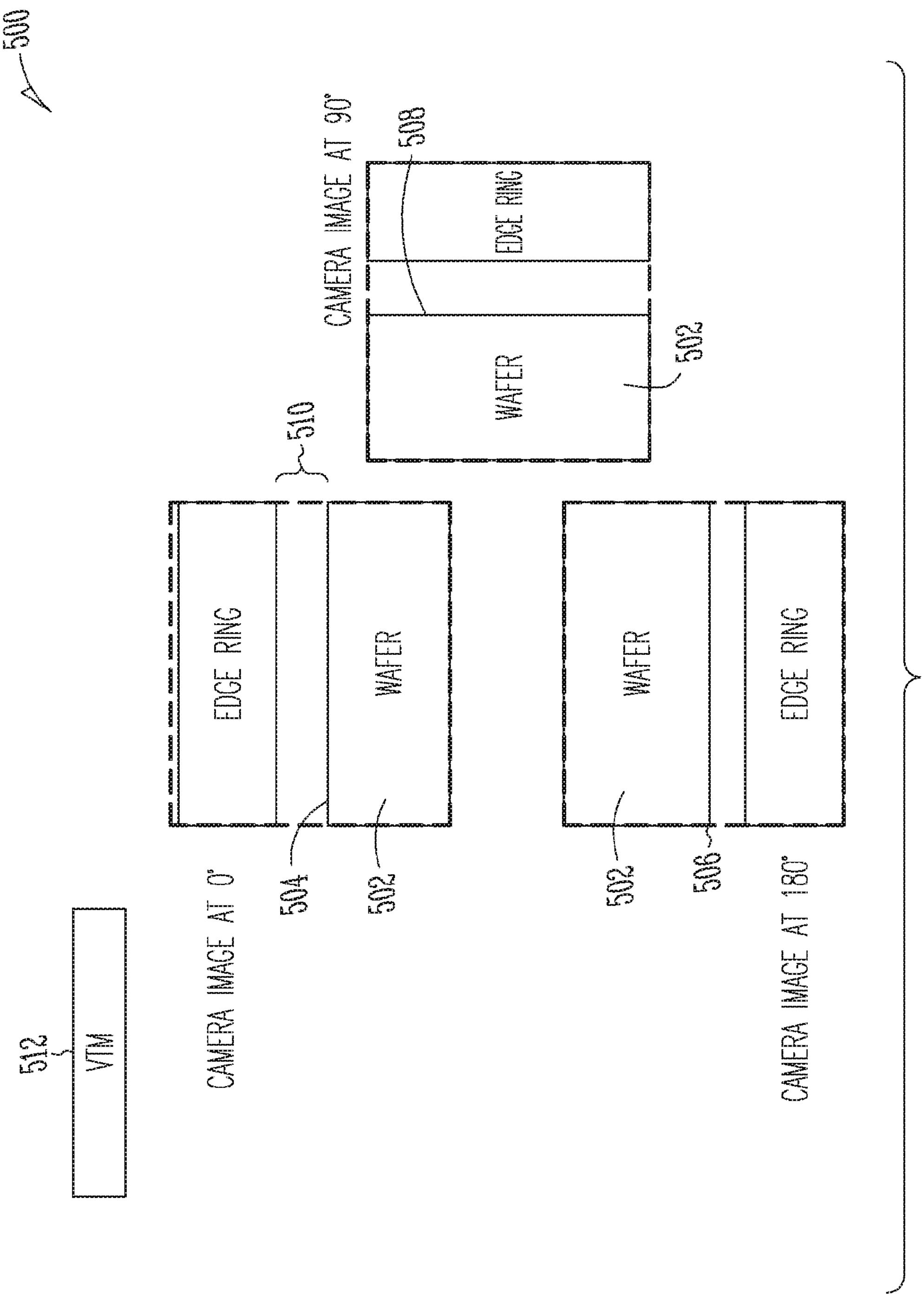

500
512
VTM
CAMERA IMAGE AT 0°
504
502
EDGE RING
WAFER
510
CAMERA IMAGE AT 90°
508
EDGE RING
WAFER
502
502
506
CAMERA IMAGE AT 180°
WAFER
EDGE RING

Fig. 5

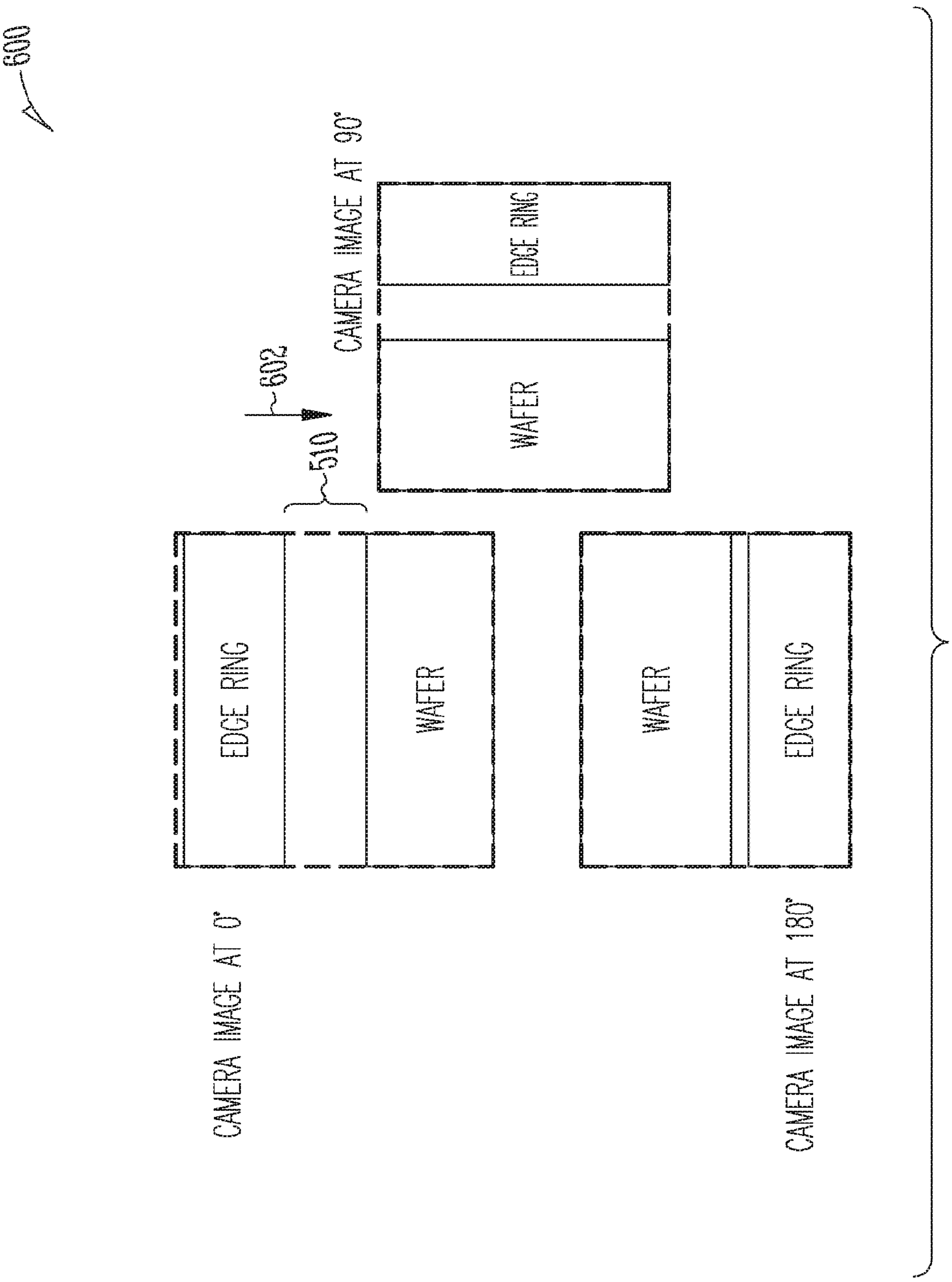

600
CAMERA IMAGE AT 90˚
EDGE RING
WAFER
602
510
EDGE RING
WAFER
CAMERA IMAGE AT 0˚
WAFER
EDGE RING
CAMERA IMAGE AT 180˚

Fig. 6

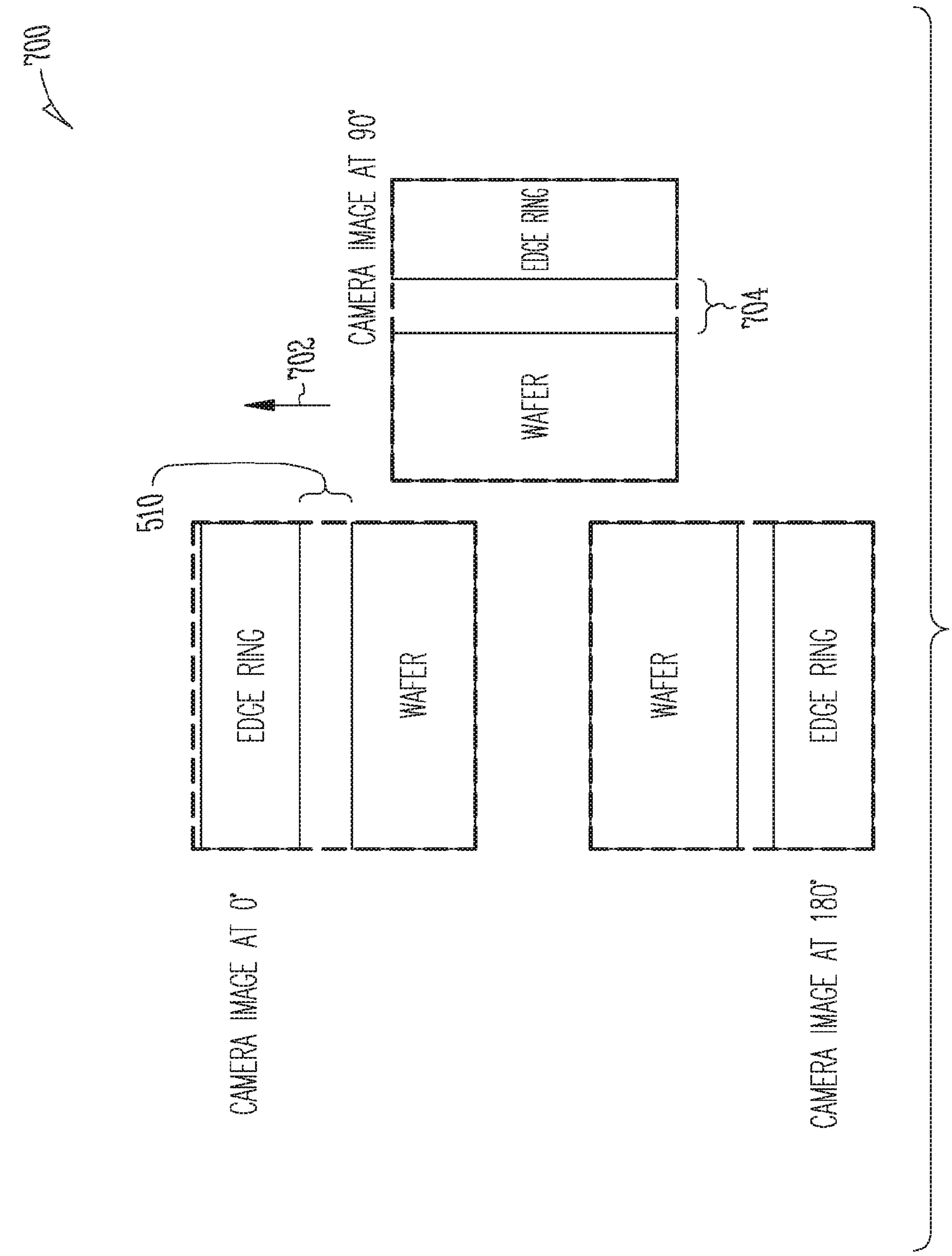

700
CAMERA IMAGE AT 90°
EDGE RING
704
702
WAFER
510
EDGE RING
WAFER
WAFER
EDGE RING
CAMERA IMAGE AT 0°
CAMERA IMAGE AT 180°

Fig. 7

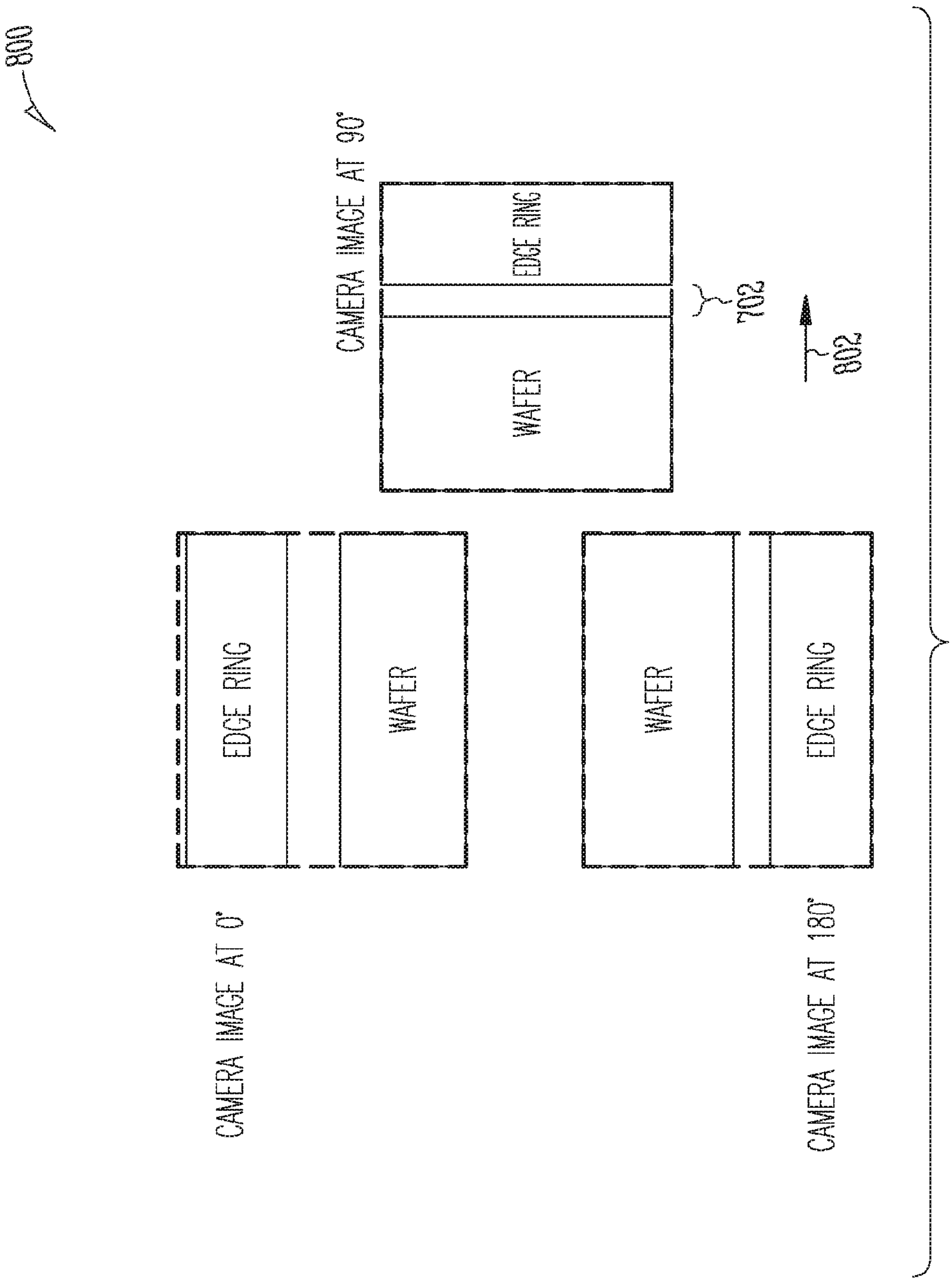
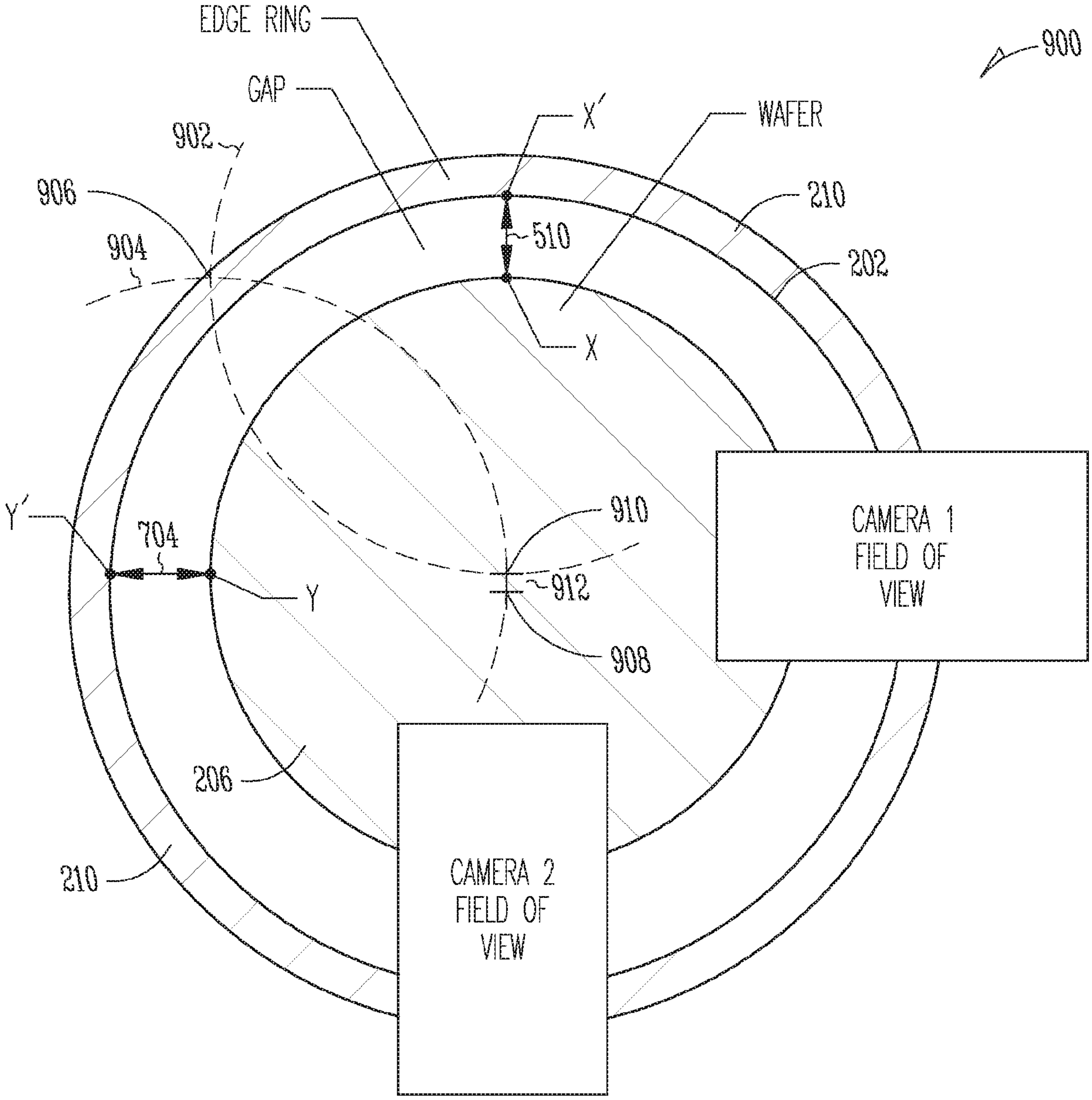

800
CAMERA IMAGE AT 90°
EDGE RING
702
WAFER
802
EDGE RING
WAFER
CAMERA IMAGE AT 0°
WAFER
EDGE RING
CAMERA IMAGE AT 180°

Fig.8



EDGE RING
900
GAP
WAFER
X′
902
906
210
510
904
202
X
CAMERA 1
FIELD OF
VIEW
Y′
910
704
912
Y
908
206
CAMERA 2
FIELD OF
VIEW
210

Fig.9

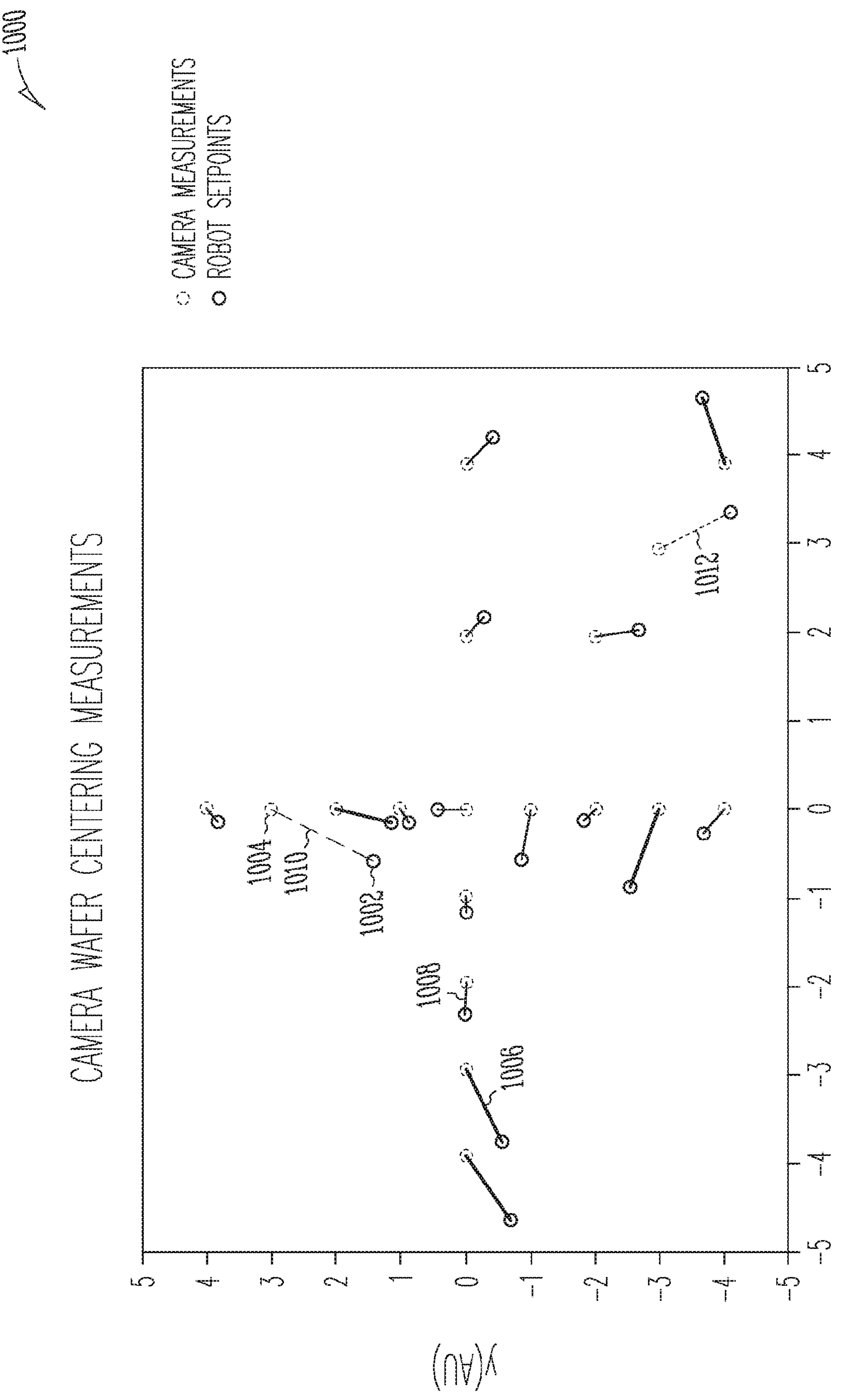

1000
CAMERA WAFER CENTERING MEASUREMENTS
CAMERA MEASUREMENTS
ROBOT SETPOINTS
1002
1004
1006
1008
1010
1012
x (AU)
y(AU)
5
4
3
2
1
0
−1
−2
−3
−4
−5

Fig. 10

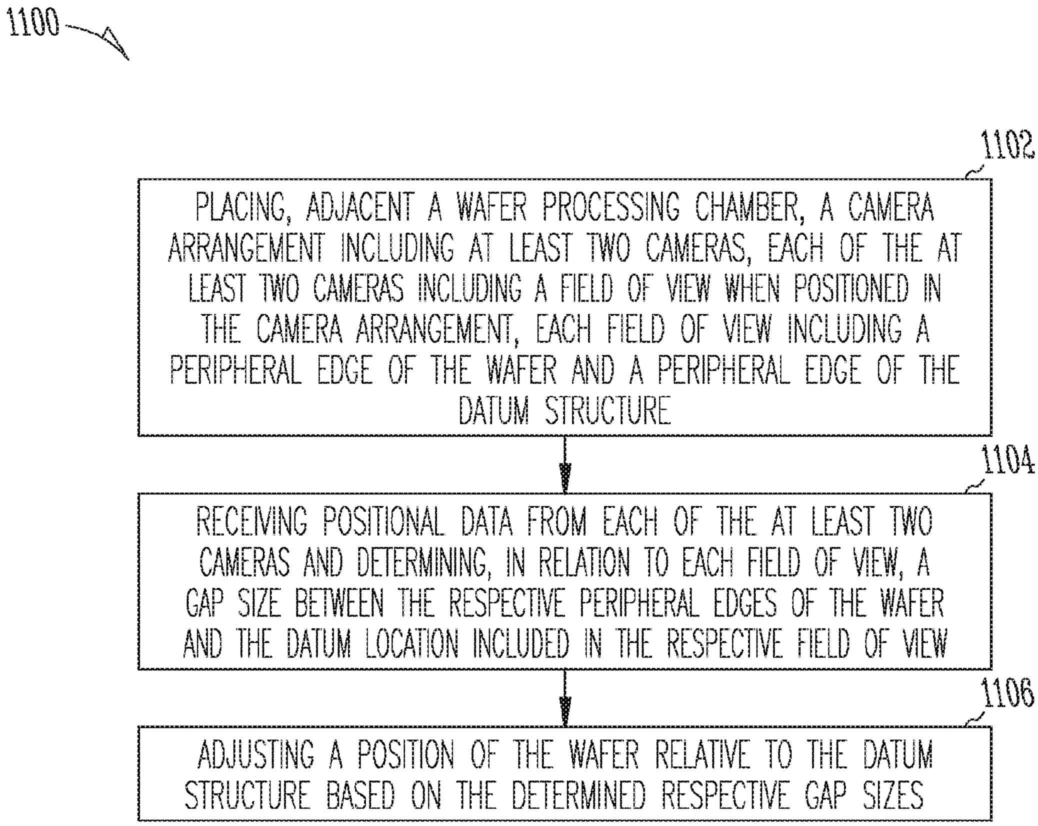

1100
1102
PLACING, ADJACENT A WAFER PROCESSING CHAMBER, A CAMERA ARRANGEMENT INCLUDING AT LEAST TWO CAMERAS, EACH OF THE AT LEAST TWO CAMERAS INCLUDING A FIELD OF VIEW WHEN POSITIONED IN THE CAMERA ARRANGEMENT, EACH FIELD OF VIEW INCLUDING A PERIPHERAL EDGE OF THE WAFER AND A PERIPHERAL EDGE OF THE DATUM STRUCTURE
1104
RECEIVING POSITIONAL DATA FROM EACH OF THE AT LEAST TWO CAMERAS AND DETERMINING, IN RELATION TO EACH FIELD OF VIEW, A GAP SIZE BETWEEN THE RESPECTIVE PERIPHERAL EDGES OF THE WAFER AND THE DATUM LOCATION INCLUDED IN THE RESPECTIVE FIELD OF VIEW
1106
ADJUSTING A POSITION OF THE WAFER RELATIVE TO THE DATUM STRUCTURE BASED ON THE DETERMINED RESPECTIVE GAP SIZES

Fig.11

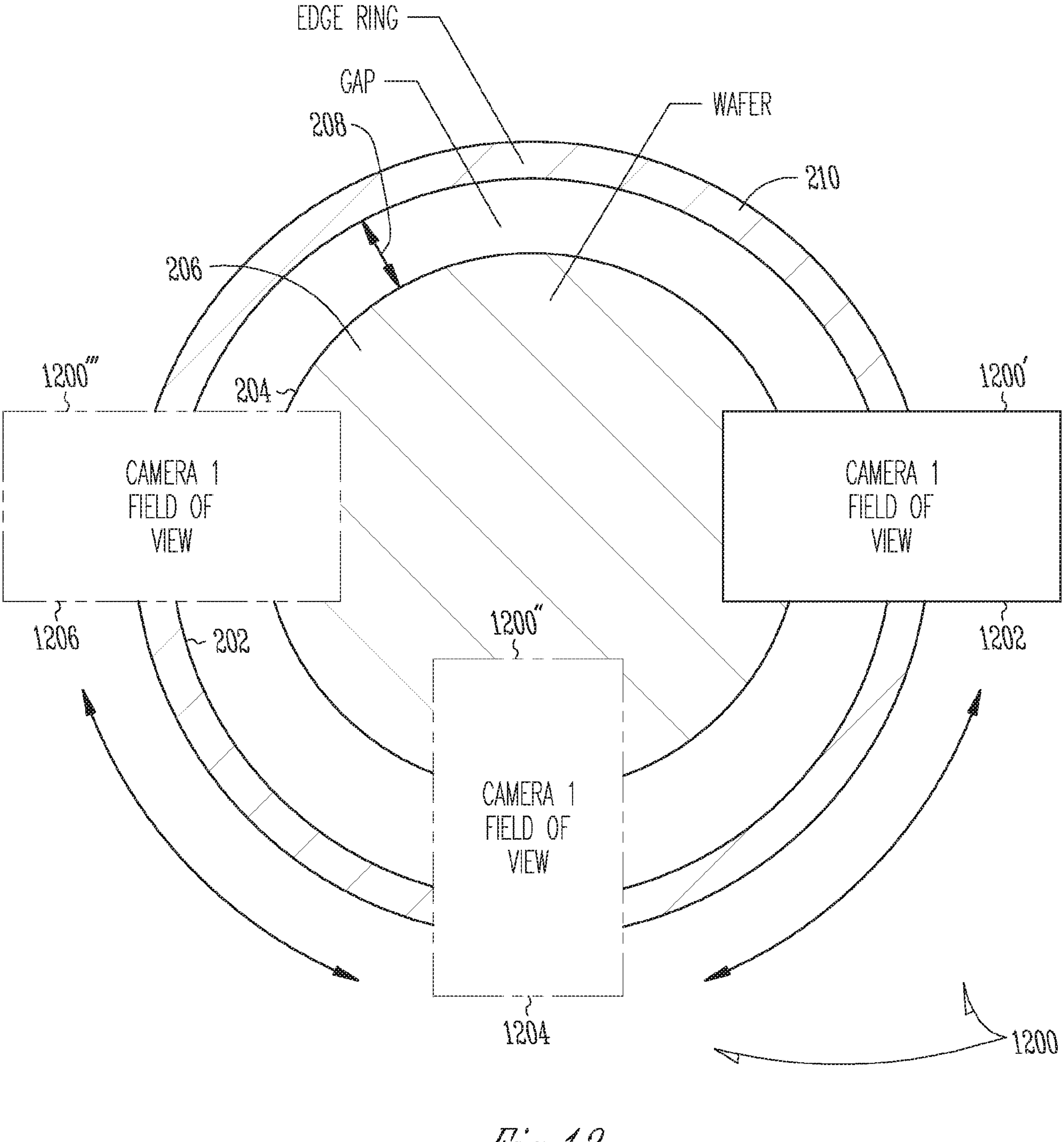

EDGE RING
GAP
208
WAFER
210
206
1200'''
204
1200'
CAMERA 1
FIELD OF
VIEW
CAMERA 1
FIELD OF
VIEW
1206
202
1200''
1202
CAMERA 1
FIELD OF
VIEW
1204
1200

Fig.12

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2020/017080

A. CLASSIFICATION OF SUBJECT MATTER

H01L 21/67(2006.01)i, H01L 21/687(2006.01)i, H01J 37/32(2006.01)i, H01L 21/683(2006.01)i, H01L 21/677(2006.01)i, G01B 11/02(2006.01)i

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)
H01L 21/67; F26B 3/30; G01R 31/26; H01L 21/66; H01L 21/677; H01L 21/68; H01L 21/683; H01L 21/687; H05B 1/00; H01J 37/32; G01B 11/02

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: positioning, wafer, datum-structure, camera, gap

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 2017-014818 A1 (APPLIED MATERIALS, INC.) 26 January 2017 Paragraphs 29-44; and figures 1A-4B.	1,3-9,11-16,20
Y		2,10,17-19
Y	US 2010-0133257 A1 (KHURSHED SORABJI et al.) 03 June 2010 Paragraph 94; and figure 10A.	2,10
Y	US 2016-0126128 A1 (BROOKS AUTOMATION, INC.) 05 May 2016 Paragraph 37; and figure 4A.	17-19
A	KR 10-2015-0005554 A (APPLIED MATERIALS, INC.) 14 January 2015 Paragraphs 24-25; and figure 1.	1-20
A	US 2008-0101912 A1 (TODD W. MARTIN et al.) 01 May 2008 The entire document.	1-20

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"D" document cited by the applicant in the international application
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"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
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
04 June 2020 (04.06.2020)	**04 June 2020 (04.06.2020)**

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2020/017080

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