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Inventor(s)	SATO; Hikaru et al.

SUBSTRATE PROCESSING APPARATUS AND POSITION DETECTION METHOD

Abstract

A substrate processing apparatus includes a processing container, a rotary table rotatably provided inside the processing container and including a stage on which a substrate is placed, an imaging device fixed to the processing container and that captures an image of a portion of the rotary table, and a control unit that processes imaging information of the imaging device. The rotary table includes at least two rotation-side imaging targets spaced apart from each other at positions corresponding to the stage. The control unit rotates the rotary table such that, when an image of the rotary table is captured, the imaging device is located between the two rotation-side imaging targets in a plan view of the imaging device and the rotary table. An intermediate correction lens is provided between the imaging device and the rotary table to correct a viewing angle direction of the imaging device.

Inventors: **SATO; Hikaru (Iwate, JP), HAGA; Yuta (Iwate, JP)**

Applicant: **Tokyo Electron Limited** (Tokyo, JP)

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application is based on and claims priority from Japanese Patent Application No. 2024-024619, filed on Feb. 21, 2024, with the Japan Patent Office, the disclosure of which is incorporated herein in its entirety by reference.

TECHNICAL FIELD

[0002] The present disclosure relates to a substrate processing apparatus and a position detection method.

BACKGROUND

[0003] Japanese Patent Laid-Open Publication No. 2012-094814 discloses a substrate processing apparatus in which substrates are respectively placed on a plurality of stages of a rotary table serving as a susceptor to perform a substrate processing such as a film forming process. This substrate processing apparatus has a camera installed in a processing container. Images of two susceptor marks on the rotary table are captured by the camera, and the position of the stage is corrected based on the imaging information. The substrate is then transported to the stage of which the position has been corrected.

SUMMARY

[0004] According to an aspect of the present disclosure, a substrate processing apparatus includes: a processing container; a rotary table rotatably provided inside the processing container and having a stage on which a substrate is placed; an imaging device fixed to the processing container and capable of capturing an image of a portion of the rotary table; and a control unit that processes imaging information of the imaging device. The rotary table includes at least two rotation-side imaging targets spaced apart from each other at positions corresponding to the stage. The control unit rotates the rotary table such that, when an image of the rotary table is captured, the imaging device is located between the two rotation-side imaging targets in a plan view of the imaging device and the rotary table. An intermediate correction lens is provided between the imaging device and the rotary table in a side view of the imaging device and the rotary table, to correct a viewing angle direction of the imaging device in a direction orthogonal to a surface of the rotary table.

[0005] The foregoing summary is illustrative only and is not intended to be in any way limiting. In addition to the illustrative aspects, embodiments, and features described above, further aspects, embodiments, and features will become apparent by reference to the drawings and the following detailed description.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0006] FIG. **1** is a schematic cross-sectional view illustrating a substrate processing apparatus according to an embodiment.

[0007] FIG. **2** is a schematic plan view illustrating the interior of a processing container of the substrate processing apparatus.

[0008] FIG. **3** is a side cross-sectional view along line III-III in FIG. **2**.

[0009] FIG. **4**A is a schematic diagram illustrating the viewing angle direction of an imaging device to which an intermediate correction lens is applied. FIG. **4**B is a schematic diagram

illustrating the viewing angle direction of the imaging device in a case where an intermediate correction lens according to a reference example is not provided.
[0010] FIG. **5** is a diagram illustrating a method of recognizing the position of a stage.
[0011] FIG. **6** is a flowchart illustrating a process flow of a position detection method.
DETAILED DESCRIPTION
[0012] In the following detailed description, reference is made to the accompanying drawings, which form a part hereof. The illustrative embodiments described in the detailed description, drawings, and claims are not meant to be limiting. Other embodiments may be utilized, and other changes may be made without departing from the spirit or scope of the subject matter presented here.
[0013] Hereinafter, an embodiment of the present disclosure will be described with reference to the accompanying drawings. In the drawings, the same components are denoted by the same reference numerals, and duplicated descriptions may be omitted.
[0014] FIG. **1** is a schematic cross-sectional view illustrating a substrate processing apparatus **100** according to an embodiment. FIG. **2** is a schematic plan view illustrating the interior of a processing container **1** of the substrate processing apparatus **100**. As illustrated in FIGS. **1** and **2**, the substrate processing apparatus **100** is configured as a film forming apparatus that forms a film on the surface of a substrate W using atomic layer deposition (ALD) or molecular layer deposition (MLD). A substrate processing performed by the substrate processing apparatus **100** is not limited to the film forming processing, and may be, for example, an etching processing or a cleaning processing.
[0015] The substrate processing apparatus **100** includes a processing container **1** for housing the substrate W therein and performing a film forming processing, and a rotary table **2** which is rotatably provided within the processing container **1**.
[0016] The processing container **1** is formed in a flat cylindrical shape and has a processing chamber therein for housing the substrate W. For example, the processing container **1** is configured by assembling a container body **12** having an open upper surface and a top plate **11** disposed on the upper portion of the container body **12**. For the convenience of description, the top plate **11** is not illustrated in FIG. **2**. The container body **12** includes a disc-shaped bottom **14** and a side **13** that protrudes vertically upward from the outer edge of the bottom **14**. The side **13** of the container body **12** and the top plate **11** are air-tightly fixed to each other with a seal member **15** such as, for example, an O-ring interposed therebetween. In addition, a position detection device **80** is installed on the top plate **11**. The configuration of this position detection device **80** will be described later in detail.
[0017] The rotary table **2** is formed in an annular shape, and has an inner periphery fixed to a cylindrical core **21**. The core **21** is fixed to the upper end of a rotating shaft **22** extending in the vertical direction. The rotating shaft **22** passes through the bottom **14** of the processing container **1**, and has a lower end held by a driving unit **23**. The driving unit **23** rotates the rotating shaft **22** about an axis. Thus, the rotary table **2** rotates around the center of the processing container **1** through the rotating shaft **22** and the core **21**.
[0018] The rotating shaft **22** and the driving unit **23** are housed in a cylindrical case body **20** having an open upper surface. The case body **20** has a flange at the upper end, and is air-tightly fixed to the bottom **14** of the processing container **1**. The internal space of the case body **20** is thus isolated from the outside of the case body **20** and is communication with the processing chamber of the processing container **1**.
[0019] As illustrated in FIGS. **1** and **2**, the rotary table **2** has, on the upper surface, a plurality of (e.g., five in FIG. **2**) circular and concave stages **24** (recesses) on which the substrate W may be placed, provided in the direction of rotation of the rotary table **2**. Examples of the substrate W on which a film forming processing is performed include semiconductor wafers such as silicon semiconductors, compound semiconductors, or oxide semiconductors. The substrate W may have

recesses and protrusions such as trenches and vias on the surface.
[0020] The stage **24** has an inner diameter slightly larger than the diameter (e.g., 300 mm) of the substrate W and a depth approximately equal to the thickness of the substrate W. As a result, in a state where the substrate W is placed on the stage **24**, the upper surface of the rotary table **2** (a region where the substrate W is not placed) and the upper surface of the substrate W are approximately at the same height.
[0021] In addition, each stage **24** of the rotary table **2** has a plurality of (e.g., three) through holes **24***h* (see, e.g., FIGS. **3** and **5**). The processing container **1** includes a lifter (not illustrated) at a position adjacent to a transport port **16** provided on the side **13**. The lifter has a plurality of (e.g., three) lift pins that move up and down through each through hole **24***h* to receive and deliver the substrate W to and from a transport device that enters through the transport port **16**.
[0022] The substrate processing apparatus **100** includes a gas supply unit **30** for supplying a gas into the inside of the processing container **1**. The gas supply unit **30** is formed of, for example, quartz and includes a plurality of gas nozzles **30**N that extend linearly. Each gas nozzle **30**N has an introduction port **30***a*, which is a base end, fixed to the side **13** of the processing container **1**, and extends radially inside the processing container **1** to near the central region. Each gas nozzle **30**N extends parallel to the upper surface of the rotary table **2** in the processing container **1**. Each gas nozzle **30**N has a plurality of gas discharge holes (not illustrated) opening toward the rotary table **2** in a thick wall on the vertically downward side. The gas discharge holes are arranged, for example, at equal intervals in the axial direction (the radial direction of the processing container **1**).
[0023] The gas supply unit **30** includes a raw material gas supply unit **31** that supplies a raw material gas, a reaction gas supply unit **32** that supplies a reaction gas, and a first separation gas supply unit **34** and a second separation gas supply unit **35** that supply a separation gas. Each of the raw material gas supply unit **31**, the reaction gas supply unit **32**, the first separation gas supply unit **34**, and the second separation gas supply unit **35** is provided with one or more gas nozzles **30**N. In the example of FIG. **2**, a second separation gas nozzle **35**N, a raw material gas nozzle **31**N, a first separation gas nozzle **34**N, and a reaction gas nozzle **32**N are installed in this order clockwise from the transport port **16**.
[0024] The raw material gas nozzle **31**N is connected to a raw material gas supply path (not illustrated). The raw material gas supply path is provided with a raw material gas source, an opening/closing valve, a flow rate controller, and the like (none of which are illustrated) to supply a raw material gas to the raw material gas nozzle **31**N. As the raw material gas, any appropriate gas may be used depending on the type of the film to be formed on the substrate W, and the like.
[0025] The reaction gas nozzle **32**N is connected to a reaction gas supply path (not illustrated). The reaction gas supply path is provided with, for example, a reaction gas source, an opening/closing valve, and a flow rate controller (none of which are illustrated) to supply a reaction gas to the reaction gas nozzle **32**N. As the reaction gas, any appropriate gas may be used depending on, for example, the type of the film to be formed on the substrate W.
[0026] The first separation gas nozzle **34**N and the second separation gas nozzle **35**N are each connected to a gas supply source of separation gas (not illustrated). Examples of the separation gas include an inert gas such as nitrogen (N.sub.2) gas or a noble gas.
[0027] In addition, the processing container **1** has two protrusions **4**A and **4**B attached to the lower surface of the top plate **11** (see also FIG. **1**). The protrusions **4**A and **4**B are generally fan-shaped in a plan view, spaced apart from each other in the circumferential direction of the processing container **1** and located above the rotary table **2**. The central sides of the protrusions **4**A and **4**B are in close proximity to a protruding portion **5** attached to the top plate **11**. The protrusions **4**A and **4**B are formed of a metal such as, for example, aluminum. The protrusion **4**A has a groove (not illustrated) extending radially in the circumferential middle portion, and houses the first separation gas nozzle **34**N in this groove. The protrusion **4**B also has a groove (not illustrated) extending radially in the circumferential middle portion, and houses the second separation gas nozzle **35**N in

this groove. Meanwhile, the processing container **1** has a first region **481** in which the raw material gas nozzle **31**N is disposed and a second region **482** in which the reaction gas nozzle **32**N is disposed between the protrusion **4**A and the protrusion **4**B located in the circumferential direction.

[0028] The protrusions **4**A and **4**B forms a separation space H (see, e.g., FIG. **1**) between these protrusions and the rotary table **2**. When a separation gas is supplied from the first separation gas nozzle **34**N and the second separation gas nozzle **35**N, the separation gas flows from the separation space H toward the first region **481** and the second region **482**. Since the height of the separation space H is lower than that of the first region **481** and the second region **482**, the pressure in the separation space H may be maintained higher than the pressure in the first region **481** and the second region **482**. This allows the separation space H to form a pressure barrier against the first region **481** and the second region **482** to reliably separate the first region **481** and the second region **482** from each other.

[0029] Referring back to FIG. **1**, a separation gas supply pipe **51** is connected to the center of the top plate **11**. By supplying the separation gas, the separation gas supply pipe **51** makes it possible for the pressure in the space between the core **21** and the top plate **11**, the space between the outer periphery of the core **21** and the inner periphery of the protruding portion **5**, and the space between the protruding portion **5** and the rotary table **2** to be maintained higher than the pressure in the first region **481** and the second region **482**.

[0030] In addition, an annular heater unit **7** serving as a heater is provided in the space between the rotary table **2** and the bottom of the container body **12**. The heater unit **7** heats each substrate W placed on the stage **24** with the rotary table **2** interposed therebetween to a target temperature. In addition, a block member **71***a* is provided below the rotary table **2** and near the outer periphery thereof so as to surround the heater unit **7**. Therefore, the space in which the heater unit **7** is placed is partitioned from the region outside the heater unit **7**. The block member **71***a* is disposed so that a small gap is maintained between the block member and the lower surface of the rotary table **2**. In order to purge a region in which the heater unit **7** is housed, a plurality of purge gas supply pipes **73** for supplying a purge gas are connected to this region so as to pass through the bottom of the container body **12**. A protective plate **7***a* is disposed above the heater unit **7**. The protective plate **7***a* is formed of quartz or the like, and protects the heater unit **7** even when processing gas flows into the space in which the heater unit **7** is provided.

[0031] In addition, the bottom of the container body **12** has a ridge R on the inside of the annular heater unit **7**. The upper surface of the ridge R is positioned close to the rotary table **2** and the core **21**, with a small gap left between the upper surface of the ridge R and the rear surface of the rotary table **2** and between the upper surface of the ridge R and the rear surface of the core **21**. The bottom **14** of the container body **12** has a central hole through which the rotating shaft **22** passes. The inner diameter of this central hole is slightly larger than the diameter of the rotating shaft **22**, with a gap that communicates with the case body **20** left therein. A purge gas supply pipe **72** is connected to the upper portion of the case body **20**.

[0032] The purge gas supply pipe **72** supplies a purge gas into the case body **20**. This purge gas flows into the space below the heater unit **7** through the gap between the rotating shaft **22** and the central hole of the bottom **14**, the gap between the core **21** and the ridge R of the bottom **14**, and the gap between the ridge R and the rear surface of the rotary table **2**. Further, the purge gas flows through the gap between the block member **71***a* and the rear surface of the rotary table **2** into exhaust ports **61** and **62** to be described later. Examples of the purge gas supplied by the purge gas supply pipe **72** and purge gas supply pipe **73** include an inert gas such as nitrogen gas or a noble gas, similarly to the separation gas.

[0033] As illustrated in FIG. **2**, the processing container **1** includes an exhaust port **61** in the first region **481** and includes an exhaust port **62** in the second region **482**. The exhaust ports **61** and **62** are connected to an exhaust system including, for example, a pressure regulator, a turbo molecular pump, and the like. The substrate processing apparatus **100** may adjust the pressure in the

processing container **1** through the exhaust system. The exhaust ports **61** and **62** may promote a reduction in the pressure in the first region **481** and the pressure in the second region **482** by exhausting the gas in the first region **481** and the gas in the second region **482**. The raw material gas supplied from the raw material gas nozzle **31**N is generally exhausted from the exhaust port **61**, and the reaction gas supplied from the reaction gas nozzle **32**N is generally exhausted from the exhaust port **62**.
[0034] In addition, the substrate processing apparatus **100** includes a control unit **90** that controls the operation of the entire apparatus. The control unit **90** is a computer having a processor, a memory, an input and output interface, and a communication interface (not illustrated). The processor is an electronic circuit including one or a combination of components such as a central processing unit (CPU), a graphics processing unit (GPU), an application specific integrated circuit (ASIC), a field-programmable gate array (FPGA), or a circuit made up of a plurality of discrete semiconductors, and executes and processes programs stored in the memory. The memory includes a main storage device such as a semiconductor memory, and an auxiliary storage device such as a disk or a semiconductor memory (flash memory).
[0035] FIG. **3** is a cross-sectional view along line III-III in FIG. **2**. As illustrated in FIG. **3**, the substrate processing apparatus **100** includes the position detection device **80** for detecting the position of each stage **24** when the substrate W is placed on each stage **24** of the rotary table **2**. The position detection device **80** is fixed to the upper portion of the top plate **11** of the processing container **1** (the outside of the processing container **1**).
[0036] The position detection device **80** includes an imaging device **81** that captures an image of the rotary table **2**, a housing **82** that houses the imaging device **81**, a panel **83** provided below the imaging device **81**, a light source **84** that irradiates an imaging target with light, an intermediate correction lens **85** that changes the viewing angle direction of the imaging device **81**, and a polarizing plate **86** that regulates reflected light. In addition, the top plate **11** of the processing container **1** has a transmission window **11***w* installed thereon so that the image of the rotary table **2** may be captured by the imaging device **81**. The transmission window **11***w* and the position detection device **80** are disposed adjacent to the transport port **16** (see also FIG. **2**). This allows the position detection device **80** to properly detect the position of the stage **24** of the rotary table **2** that has moved to the vicinity of the transport port **16**.
[0037] The imaging device **81** is provided at a position spaced apart from the transmission window **11***w* by an imaging distance set in the vertical direction. The type of imaging device **81** is not particularly limited, and, for example, a camera having a charge coupled device (CCD) sensor or a complementary metal oxide semiconductor (CMOS) sensor may be applied. The imaging device **81** is attached to the upper portion inside the housing **82**, with an internal lens facing the vertically downward side. This allows the imaging device **81** to capture images of a portion of the rotary table **2** and a periphery thereof through the transmission window **11***w* of the top plate **11**. The imaging device **81** causes an imaging control unit **81***a* connected thereto to control on/off switching, focusing, imaging, or the like, and to process imaging information on captured images. The imaging control unit **81***a* may also serve as the control unit **90**.
[0038] The housing **82** is formed in a cylindrical shape, holds the imaging device **81** at the upper portion, and blocks light from the surroundings in the imaging direction of the imaging device **81**. The lower end of the housing **82** is formed as an opening, and the housing **82** is installed on the top plate **11** with the opening facing the transmission window **11***w*. In addition, the housing **82** may be provided with a cooling mechanism (not illustrated) that cools the imaging device **81**. The cooling mechanism may have, for example, a configuration in which a fan (not illustrated) blows air onto the imaging device **81** and the light source **84**, and exhausts the air from an opening (not illustrated).
[0039] The panel **83** is provided between the imaging device **81** and the transmission window **11***w* which are aligned vertically in a side view. The panel **83** has an aperture **83***a* in a central portion

thereof. The imaging device **81** captures an image of an imaging range F defined by the aperture **83***a*. Specifically, as illustrate in FIG. **2**, the imaging range F is defined so a portion of the outer periphery of the rotary table **2** and a portion of the container body **12** are captured in the image. In addition, the imaging range F is defined such that the radially outer side of the stage **24** that has moved due to the rotation of the rotary table **2** is captured in the image.

[0040] Here, the rotary table **2** is provided in advance with two rotation-side imaging targets **25** corresponding to each of a plurality of stages **24**. The position detection device **80** sets the imaging distance of the imaging device **81** and the position or size of the aperture **83***a* such that the two rotation-side imaging targets **25** are entered therein. In addition, the processing container **1** also has two fixed-side imaging targets **17** so as to be adjacent to the two rotation-side imaging targets **25** that have moved due to the rotation of the rotary table **2**. In other words, the position detection device **80** may capture images of the two rotation-side imaging targets **25** and the two fixed-side imaging targets **17** using the imaging device **81**, and detects the position of the rotary table **2** in the rotational direction (circumferential direction) based on the imaging information.

[0041] Each rotation-side imaging target **25** and each fixed-side imaging target **17** are formed in a perfect circular shape in a plan view. However, the shapes of the rotation-side imaging target **25** and the fixed-side imaging target **17** are not particularly limited, and may be, for example, polygonal or elliptical. In addition, each fixed-side imaging target **17** is formed to have a size (diameter) slightly larger than each rotation-side imaging target **25**. This allows the imaging control unit **81***a* to easily identify each rotation-side imaging target **25** and each fixed-side imaging target **17** of which the images have been captured.

[0042] Referring back to FIG. **3**, each rotation-side imaging target **25** is formed in a recess **251** recessed from the surface (upper surface) of the rotary table **2** in a thickness direction. By carving the recess **251** into the rotary table **2** in this way, a luminance difference occurs between the surface of the rotary table **2** and the surface of the recess **251**. The imaging control unit **81***a* extracts the edge of the rotation-side imaging target **25** from this luminance difference, and further recognizes the circle of the recess **251** by using a Hough transform algorithm. In addition, similarly, each fixed-side imaging target **17** is also formed in a recess **171** (see, e.g., FIG. **2**) recessed from the surface (upper surface) of the bottom **14** of the container body **12** in the thickness direction. The rotation-side imaging target **25** and the fixed-side imaging target **17** are not limited to the configurations of only the recesses **251** and **171**, and may be configured with, for example, a black marker or the like housed therein.

[0043] The light source **84** of the position detection device **80** is attached so as to irradiate the imaging range F defined by the aperture **83***a* with light through a hole **83***b* in the panel **83** and the transmission window **11***w*. The light source **84** may be, for example, an illumination device having a white light-emitting diode (LED), and the brightness is adjusted by a driving unit (not illustrated). In FIG. **3**, the configuration has two light sources **84** to ensure brightness, but the number of light sources **84** is not particularly limited, and may be one, or three or more. In addition, the light source **84** may be installed at a changeable angle. The light source **84** irradiates the rotary table **2** with light, so that the two rotation-side imaging targets **25** and the two fixed-side imaging targets **17** are appropriately illuminated.

[0044] The intermediate correction lens **85** is provided between the imaging device **81** and the rotary table **2** in a side view of the imaging device **81** and the rotary table **2**. The intermediate correction lens **85** may be formed of transparent quartz or a resin material. More specifically, the intermediate correction lens **85** is disposed below the panel **83** and at a position away from the transmission window **11***w*. The intermediate correction lens **85** has a function of correcting the viewing angle direction of the imaging device **81** in a direction orthogonal to the surface of the rotary table **2**.

[0045] FIG. **4**A is a schematic diagram illustrating the viewing angle direction VD of the imaging device **81** to which the intermediate correction lens **85** is applied. FIG. **4**B is a schematic diagram illustrating the viewing angle direction VD of the imaging device **81** in a case where the intermediate correction lens **85** according to a reference example is not provided. The imaging device **81** is configured so that the angle of view is formed by an imaging lens housed inside, whereby the viewing angle direction VD becomes more diagonal to the side as it moves toward the outside of the imaging range F as illustrated in FIGS. **4**A and **4**B. In positioning the stage **24**, the imaging device **81** basically captures images at the middle positions of the two fixed-side imaging targets **17** and the two rotation-side imaging targets **25** (see, e.g., FIG. **2**). Therefore, the two fixed-side imaging targets **17** and the two rotation-side imaging targets **25** are each located closer to the edge of the imaging range F.

[0046] As illustrated in FIG. **4**B, a position detection device **80**′ according to the reference example captures an image of the imaging range F without correcting the viewing angle direction VD, so that each fixed-side imaging target **17** and each rotation-side imaging target **25** are viewed diagonally to the side, and it is not possible to capture an image as if viewed from directly above. In other words, the imaging device **81** captures imaging information for the recess **171** of each fixed-side imaging target **17** and the recess **251** of each rotation-side imaging target **25**, in which the edge of the opening and the edge of the bottom are doubled. In this case, the acquisition of double circles in the image processing of the imaging control unit **81***a* makes it difficult for the control unit **90** to determine the accurate positions of each fixed-side imaging target **17** and each rotation-side imaging target **25**.

[0047] For this reason, the position detection device **80** according to the embodiment performs image capture using the imaging device **81** through the intermediate correction lens **85**, as illustrated in FIG. **4**A. The intermediate correction lens **85** bends the viewing angle direction VD of the imaging device **81** to thereby correct the optical path to be perpendicular to the surface of the bottom **14** of the container body **12** and the surface of the rotary table **2** (in other words, each fixed-side imaging target **17** and each rotation-side imaging target **25**). That is, the intermediate correction lens **85** reduces the effect of the angle of view caused by the lens in the imaging device **81** as described above, and sets the viewing angle direction VD as if each fixed-side imaging target **17** and each rotation-side imaging target **25** are viewed from directly above. This allows the imaging device **81** to obtain imaging information in which the recess **171** of each fixed-side imaging target **17** and the recess **251** of each rotation-side imaging target **25** do not appear double.

[0048] The intermediate correction lens **85** applied to the position detection device **80** has no particular limitation on structure insofar as it may correct the viewing angle direction VD in the vertical direction. For example, the intermediate correction lens **85** may be appropriately selected from a convex lens, a Fresnel lens, a cylindrical lens, and a combination of a convex lens and a concave lens. In addition, the intermediate correction lens **85** is formed in a rectangular of elliptical shape having a major axis in the extending direction of the transmission window **11***w* in a plan view. The size of the intermediate correction lens **85** may be, for example, approximately the same as that of the transmission window **11***w*. The intermediate correction lens **85** may also guide light which is approximately perpendicular to each fixed-side imaging target **17** and each rotation-side imaging target **25** by making the light from the light source **84** approximately parallel to the vertical direction.

[0049] The position detection device **80** refracts the optical paths of the imaging device **81** and the light source **84** to thereby change the reflection position of light that hits the rotary table **2** and the container body **12** and the intensity of reflected light. For this reason, there is concern of strong reflected light being generated at specific positions of the rotary table **2** and the container body **12**. In order to suppress the imaging device **81** from capturing an image of this local reflected light, the position detection device **80** includes a polarizing plate **86** between the intermediate correction lens **85** and the rotary table **2**.

[0050] The polarizing plate **86** removes the local reflected light from the rotary table **2** and the container body **12** by adjusting the reflected light that vibrates in all directions to light that vibrates only a specific direction. A well-known configuration may be applied to the polarizing plate **86**. Alternatively, the polarizing plate **86** may be configured to be disposed on the light source **84** side to polarize the irradiation light from the light source **84** in advance.

[0051] In addition, in a case where the intermediate correction lens **85** and the polarizing plate **86** are applied, the imaging device **81** may acquire imaging information which is dark overall (low in luminance). For this reason, the imaging device **81** is recommended to perform a processing of adjusting the imaging information to achieve appropriate luminance in the image processing performed by the imaging control unit **81***a*. An example of the image processing performed by the imaging control unit **81***a* is a high dynamic range (HDR) processing.

[0052] The imaging control unit **81***a* extracts information on each fixed-side imaging target **17** and each rotation-side imaging target **25** from the imaging information by performing a further image processing on the imaging information that has undergone the HDR processing. An example of the processing of extracting each fixed-side imaging target **17** and each rotation-side imaging target **25** is Hough transform. By performing the Hough transform, it is possible to detect the circle of each fixed-side imaging target **17** and the circle of each rotation-side imaging target **25**. As described above, the imaging information of the imaging device **81** is corrected by the intermediate correction lens **85**, which prevents the openings and bottoms of the recesses **171** and **251** from being doubled. Therefore, the imaging control unit **81***a* may easily obtain the circle of each fixed-side imaging target **17** and the circle of each rotation-side imaging target **25** with few errors (candidates) in the Hough transform.

[0053] The control unit **90** recognizes the position of each stage **24** of the rotary table **2** facing the position detection device **80** by using information on the circle of the fixed-side imaging target **17** and the circle of each rotation-side imaging target **25** obtained from the imaging device **81**.

[0054] FIG. **5** is a diagram illustrating a method of recognizing the position of the stage **24**. Specifically, the control unit **90** detects the position of each target from the circle of the fixed-side imaging target **17** and the circle of each rotation-side imaging target **25** acquired from the imaging device **81**.

[0055] Here, the two rotation-side imaging targets **25** are disposed symmetrically with respect to a straight line passing through a center **24***c* of the stage **24** and a rotation center Rc of the rotary table **2**. In other words, when a perpendicular line N**1** is drawn from the rotation center **2***c* of the rotary table **2** to a segment L**1** connecting the centers of the two rotation-side imaging targets **25**, this perpendicular line N**1** passes through the center **24***c* of the stage **24** and intersects the midpoint of the segment L**1**. That is, the perpendicular line N**1** is the perpendicular bisector of the segment L**1**.

[0056] In addition, when a perpendicular line N**2** is drawn from the rotation center Rc of the rotary table **2** to a segment L**2** connecting the centers of the two fixed-side imaging targets **17**, this perpendicular line N**2** intersects the midpoint of the segment L**2**. That is, the perpendicular line N**2** is the perpendicular bisector of the segment L**2**.

[0057] The angle θ between the perpendicular line N**1** and the perpendicular line N**2** is the shift of the stage **24** when the rotary table **2** is rotated to place the substrate W. That is, in a case where the angle θ is approximately zero, the stage **24** may be assumed to be disposed at a normal position where the substrate W may be placed, whereas in a case where the angle θ is greater than a predetermined value, the shift of the stage **24** may be assumed to need to be adjusted.

[0058] In a case where the shift of the stage **24** is adjusted, the control unit **90** is recommended to perform a processing of rotating the rotary table **2** by the shift amount based on the detected angle θ and the position of the center **24***c* of the stage **24**. This ensures that the angle θ becomes zero and the stage **24** is appropriately positioned, which makes it possible for the substrate W to be accurately placed on the stage **24** by the transport device.

[0059] The substrate processing apparatus **100** according to the embodiment is basically configured as described above, and a method of detecting the position of the stage **24** when the substrate W is placed will be described below with reference to FIG. **6**. FIG. **6** is a flowchart illustrating a process flow of the position detection method.

[0060] The control unit **90** and the imaging control unit **81***a* of the substrate processing apparatus **100** control steps S**101** to S**109** in the position detection method.

[0061] Specifically, in the position detection method, the substrate processing apparatus **100** rotates the rotary table **2** to move the stage **24** which is a target to a position adjacent to the transport port **16** of the processing container **1** (step S**101**). This movement causes the imaging device **81** to be located between the two rotation-side imaging targets **25** in a plan view of the imaging device **81** and the rotary table **2**.

[0062] Next, the control unit **90** operates the imaging device **81** of the position detection device **80** and captures an image of a portion of the rotary table **2** including the stage **24** using the imaging device **81** to start detecting the position of the stage **24** (step S**102**). As described above, the imaging control unit **81***a* captures images of the two fixed-side imaging targets **17** and the two rotation-side imaging targets **25** through the intermediate correction lens **85** to thereby acquire imaging information having these imaging targets.

[0063] When the imaging information is acquired, the imaging control unit **81***a* performs the HDR processing on the imaging information whose luminance has been decreased by passing through the intermediate correction lens **85** and the polarizing plate **86**, to thereby improve the luminance (step S**103**).

[0064] Next, the imaging control unit **81***a* generates an edge detection image by extracting the edges of each fixed-side imaging target **17** and each rotation-side imaging target **25** based on the luminance change in the imaging information with improved luminance (step S**104**). For example, the edge detection image is information on a binary image in which areas where the luminance change is equal to or greater than a threshold are set to be white, and areas where the luminance change is less than the threshold are set to be black.

[0065] The imaging control unit **81***a* performs a processing of detecting the circle of each fixed-side imaging target **17** and the circle of each rotation-side imaging target **25** from the edge detection image through the Hough transform (step S**105**). This allows the imaging control unit **81***a* to obtain the circles of the two fixed-side imaging targets **17** and the circles of the two rotation-side imaging targets **25** (four circles in total) described above. The imaging control unit **81***a* transmits the extracted images for the circles of the two fixed-side imaging targets **17** and the circles of the two rotation-side imaging targets **25** to the control unit **90**.

[0066] When the extracted images are acquired, the control unit **90** calculates the center coordinates (that is, the positions of each fixed-side imaging target **17** and each rotation-side imaging target **25**) and the radius of each circle from the extracted images (step S**106**).

[0067] Further, the control unit **90** calculates the angle θ between the perpendicular line N**1** and the perpendicular line N**2** described above and the position of the center **24***c* of the stage **24** based on the calculated positions of each fixed-side imaging target **17** and each rotation-side imaging target **25** (step S**107**). This angle θ represents the shift amount of the stage **24** as described above.

[0068] The control unit **90** determines whether the shift amount (angle θ) of the stage **24** falls within a threshold (step S**108**). In a case where the shift amount exceeds the threshold (step S**108**: NO), the process returns to step S**101**, and the rotary table **2** is rotated to readjust the position of the stage **24**. In this case, the rotary table **2** need only be rotated based on the angle θ detected in step S**107**. Meanwhile, in a case where the shift amount falls within the threshold (step S**108**: YES), the process proceeds to step S**109**.

[0069] In step S**109**, the control unit **90** controls the transport device to load the substrate W into the processing container **1** using the transport device and place the substrate W on the stage **24**. In this case, the control unit **90** may finely adjust the position of the substrate W using the transport device based on the position of the center **24***c* of the stage **24** calculated in step S**107**. In addition, the substrate processing apparatus **100** is configured with the shift amount of the rotational position of the rotary table **2** falling within the threshold. Therefore, when each lift pin is raised from each

through hole **24***h*, contact of each lift pin with the rotary table **2** may be avoided. This allows the substrate processing apparatus **100** to stably place the substrate W on the stage **24**.
[0070] In the above-described position detection method, the processing of loading the substrate W onto the stage **24** has been described as an example, but there is no limitation thereto. The same applies to a processing of unloading the substrate W from the stage **24**.
[0071] As described above, the substrate processing apparatus **100** and the position detection method make it possible to accurately capture images of each fixed-side imaging target **17** and each rotation-side imaging target **25** using the imaging device **81** through the intermediate correction lens **85**, and to detect the positions thereof. As a result, the substrate processing apparatus **100** and the position detection method make it possible to accurately position the stage **24**.
[0072] The substrate processing apparatus **100** and the position detection method of the present disclosure are not limited to the above-described embodiment, and may take various modification examples. For example, the substrate processing apparatus **100** may not include the polarizing plate **86** in a case where strong reflected light is not generated on the rotary table **2** or the container body **12**. In addition, the substrate processing apparatus **100** may omit the HDR processing or the like in a case where there is a small decrease in luminance of the imaging information.
[0073] In addition, for example, insofar as at least two rotation-side imaging targets **25** are provided for each stage **24**, the substrate processing apparatus **100** may detect the position of the stage **24** based on the positional relationship with an appropriate configuration of the processing container **1** or the positional relationship in the imaging range. Therefore, the substrate processing apparatus **100** does not need to have the fixed-side imaging target **17**. For example, in a case where the position of the rotation-side imaging target **25** is extracted using the position of each pixel of the imaging information, the substrate processing apparatus **100** may calculate the position of the rotation-side imaging target **25** regardless of the Hough transform.
[0074] Further, the substrate processing apparatus **100** may be configured to have the intermediate correction lens **85** below the transmission window **11***w* (inside the processing container **1**). Alternatively, the substrate processing apparatus **100** may be configured with the intermediate correction lens **85** applied instead of the transmission window **11***w*.
[0075] Furthermore, although the rotary table **2** having a plurality of fixed concave stages **24** has been described in the embodiment, the substrate processing apparatus **100** may be configured to rotate (spin) each stage **24** separately from the rotation (revolution) of the rotary table **2**. In the case of a configuration in which each stage **24** is rotated, at least two imaging targets (for example, recesses) are also formed in each stage **24**, and the position of the stage **24** in the rotational direction is recognized by the imaging device **81**, which makes it possible to position the stage **24**.
[0076] The technical ideas and effects of the present disclosure described in the above embodiment will be described below.
[0077] According to a first aspect of the present disclosure, there is provided a substrate processing apparatus **100** including: a processing container **1**; a rotary table **2** rotatably provided inside the processing container **1** and including a stage **24** on which a substrate W is placed; an imaging device **81** fixed to the processing container **1** and capable of capturing an image of a portion of the rotary table **2**; and a control unit (an imaging control unit **81***a* or a control unit **90**) that processes imaging information of the imaging device **81**, in which the rotary table **2** includes at least two rotation-side imaging targets **25** spaced apart from each other at positions corresponding to the stage, the control unit **90** rotates the rotary table **2** such that, when an image of the rotary table **2** is captured, the imaging device **81** is located between the two rotation-side imaging targets **25** in a plan view of the imaging device **81** and the rotary table **2**, and an intermediate correction lens **85** is provided between the imaging device **81** and the rotary table **2** in a side view of the imaging device **81** and the rotary table **2**, to correct a viewing angle direction VD of the imaging device **81** in a direction orthogonal to a surface of the rotary table **2**.
[0078] According to the above, the substrate processing apparatus **100** includes the intermediate

correction lens **85**, and thus it is possible to clearly capture at least two rotation-side imaging targets **25** when the imaging device **81** captured an image. The control unit (the imaging control unit **81***a*, the control unit **90**) may accurately recognize the position of the stage **24** of the rotary table **2** by using this imaging information. This enables the substrate processing apparatus **100** to accurately position the stage **24** by rotating the rotary table **2**, and to accurately place the substrate W on the stage **24**.

[0079] In addition, the processing container **1** includes at least two fixed-side imaging targets **17** spaced apart from each other in an imaging range F captured by the imaging device **81**, and the imaging device **81** captures images of the two rotation-side imaging targets **25** and the two fixed-side imaging targets **17** through the intermediate correction lens **85**. This allows the substrate processing apparatus **100** to recognize the shift between the imaging targets by using information on the two rotation-side imaging targets **25** and the two fixed-side imaging targets **17**.

[0080] In addition, the control unit (the imaging control unit **81***a* or the control unit **90**) performs an image processing on the two rotation-side imaging targets **25** and the two fixed-side imaging targets **17** included in the imaging information to detect positions of the two rotation-side imaging targets **25** and positions of the two fixed-side imaging targets **17**. This allows the substrate processing apparatus **100** to more accurately calculate the positional shift of the stage **24** based on the positions of the two rotation-side imaging targets **25** and the positions of the two fixed-side imaging targets **17**.

[0081] In addition, the control unit (the imaging control unit **81***a*, the control unit **90**) performs a high dynamic range (HDR) processing to improve luminance of the imaging information as the image processing. This allows the application of the intermediate correction lens **85** to improve the luminance of the imaging information even when there is a decrease in the luminance, and to increase the accuracy of identification of the two rotation-side imaging targets **25** and the two fixed-side imaging targets **17**.

[0082] In addition, the control unit (the imaging control unit **81***a* or the control unit **90**) performs Hough transform on the two rotation-side imaging targets **25** as the image processing, thereby detecting a predetermined shape. This allows the substrate processing apparatus **100** to more accurately calculate the positions of the two rotation-side imaging targets **25** based on the Hough transformed shapes.

[0083] In addition, a polarizing plate **86** is provided between the intermediate correction lens **85** and the rotary table **2** in a side view of the imaging device **81** and the rotary table **2**. This allows the substrate processing apparatus **100** to remove reflected light from the processing container **1** and the rotary table **2** using the polarizing plate **86**, and to stably execute the extraction of the two rotation-side imaging targets **25**.

[0084] In addition, the imaging device **81** is provided outside the processing container **1**, the processing container **1** has a transmission window **11***w* through which the imaging device **81** is capable of capturing an image of the rotary table **2**, and the intermediate correction lens **85** is provided between the transmission window **11***w* and the imaging device **81**. This allows the substrate processing apparatus **100** to suppress contamination of the intermediate correction lens **85** concomitant with substrate processing.

[0085] In addition, the two rotation-side imaging targets **25** are recesses **251** recessed from the surface of the rotary table **2** in the thickness direction. This allows the substrate processing apparatus **100** to reduce manufacturing costs, and allows the imaging device **81** and the intermediate correction lens **85** to capture straight images of the recesses **251** and properly detect the positions thereof.

[0086] In addition, according to a second aspect of the present disclosure, there is provided a method of detecting a position of a substrate processing apparatus **100**, the apparatus including a processing container **1**, a rotary table **2** rotatably provided inside the processing container **1**, including a stage **24** on which a substrate W is placed, and having at least two rotation-side imaging targets **25** spaced apart from each other at positions corresponding to the stage **24**, and an imaging device **81** fixed to the processing container **1** and capable of capturing an image of a portion of the rotary table **2**, the method including: (A) rotating the rotary table **2** such that the imaging device **81** is located between the two rotation-side imaging targets **25** in a plan view of the imaging device **81** and the rotary table **2**; (B) after (A), capturing images of the two rotation-side imaging targets **25** by correcting a viewing angle direction VD of the imaging device **81** in a direction orthogonal to a surface of the rotary table **2** through an intermediate correction lens **85** provided between the imaging device **81** and the rotary table **2** in a side view of the imaging device **81** and the rotary table **2**; (C) performing an image processing on imaging information captured by the imaging device **81** in (B), thereby detecting positions of the two rotation-side imaging targets **25**. Even in this case, the position detection method makes it possible to accurately recognize the position of the stage **24** of the rotary table **2**.

[0087] According to an aspect, the position of the stage of the rotary table may be recognized with high accuracy.

[0088] From the foregoing content, it will be appreciated that various embodiments of the present disclosure have been described herein for purposes of illustration, and that various modifications can be made without departing from the scope and spirit of the present disclosure. Accordingly, the various embodiments disclosed herein are not intended to be limiting, with the true scope and spirit being indicated by the following claims.

Claims

1. A substrate processing apparatus comprising: a processing container; a rotary table rotatably provided inside the processing container and including a stage on which a substrate is placed; an imaging device fixed to the processing container and configured to capture an image of a portion of the rotary table; and a controller configured to process imaging information of the imaging device, wherein the rotary table includes at least two rotation-side imaging targets spaced apart from each other at positions corresponding to the stage, the controller rotates the rotary table such that, when an image of the rotary table is captured, the imaging device is located between the two rotation-side imaging targets in a plan view of the imaging device and the rotary table, and an intermediate correction lens is provided between the imaging device and the rotary table in a side view of the imaging device and the rotary table, to correct a viewing angle direction of the imaging device in a direction orthogonal to a surface of the rotary table.

2. The substrate processing apparatus according to claim 1, wherein the processing container includes at least two fixed-side imaging targets spaced apart from each other in an imaging range imaged by the imaging device, and the imaging device captures images of the two rotation-side imaging targets and the two fixed-side imaging targets through the intermediate correction lens.

3. The substrate processing apparatus according to claim 2, wherein the controller performs an image processing on the two rotation-side imaging targets and the two fixed-side imaging targets included in the imaging information to detect positions of the two rotation-side imaging targets and positions of the two fixed-side imaging targets.

4. The substrate processing apparatus according to claim 3, wherein the controller performs a high dynamic range (HDR) processing to improve luminance of the imaging information as the image processing.

5. The substrate processing apparatus according to claim 3, wherein the controller performs a Hough transform on the two rotation-side imaging targets as the image processing, thereby detecting a predetermined shape.

6. The substrate processing apparatus according to claim 1, wherein a polarizing plate is provided between the intermediate correction lens and the rotary table in a side view of the imaging device and the rotary table.

7. The substrate processing apparatus according to claim 1, wherein the imaging device is provided outside the processing container, the processing container has a transmission window through which the imaging device is capable of capturing an image of the rotary table, and the intermediate correction lens is provided between the transmission window and the imaging device.

8. The substrate processing apparatus according to claim 1, wherein the two rotation-side imaging targets are recesses recessed from the surface of the rotary table in a thickness direction thereof.

9. A position detection method comprising: providing a substrate processing apparatus including: a processing container, a rotary table rotatably provided inside the processing container, including a stage on which a substrate is placed, and having at least two rotation-side imaging targets spaced apart from each other at positions corresponding to the stage, and an imaging device fixed to the processing container and configured to capture an image of a portion of the rotary table; rotating the rotary table such that the imaging device is located between the two rotation-side imaging targets in a plan view of the imaging device and the rotary table; after the rotating, capturing images of the two rotation-side imaging targets by correcting a viewing angle direction of the imaging device in a direction orthogonal to a surface of the rotary table through an intermediate correction lens provided between the imaging device and the rotary table in a side view of the imaging device and the rotary table; and performing an image processing on imaging information captured by the imaging device in the capturing, thereby detecting positions of the two rotation-side imaging targets.