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Inventor(s)	Oshima; Tomoyuki et al.

Substrate processing system and method of teaching transfer device

Abstract

A substrate processing system includes a load-lock module including load-lock module stages, a process module including process module stages, a vacuum transfer module that connects the load-lock module to the process module, a first transfer device that transfers substrates from the load-lock module stages to the process module stages, the first transfer device being provided in the vacuum transfer module, a second transfer device that transfers the substrates to the load-lock module stages, and a processor. The processor is configured to perform teaching a position at which the first transfer device receives the substrates from the load-lock module, teaching a position at which the first transfer device delivers the substrates to the process module, measuring shift amounts between the process module stages and the substrates mounted thereon, and correcting positions at which the second transfer device delivers the substrates to the load-lock module stages based on the measured shift amounts.

Inventors: **Oshima; Tomoyuki (Tokyo, JP), Shindo; Takehiro (Yamanashi, JP)**

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

Family ID: **1000008764546**

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

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Primary Examiner: Mott; Adam R

Assistant Examiner: Gammon; Matthew C

Attorney, Agent or Firm: IPUSA, PLLC

Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS

(1) This patent application is based on and claims priority to Japanese Patent Application No. 2021-159748 filed on Sep. 29, 2021, the entire contents of which are incorporated herein by reference.

TECHNICAL FIELD

(2) The present disclosure relates to a substrate processing system and a method of teaching a transfer device.

BACKGROUND

(3) Patent Document 1 discloses a substrate processing system including a load-lock module including multiple stages, a process chamber (a process module) including multiple stages, and a transfer device configured to transfer multiple substrates mounted on the stages of the load-lock module to the stages of the process module.

(4) The position of the stage in the process module has individual error with respect to a design value. Additionally, the error differs for each process module.

(5) One aspect of the present disclosure provides a substrate processing system that transfers a substrate in consideration of a shift of a stage and a method of teaching a transfer device.
RELATED ART DOCUMENT
(6) [Patent Document]
(7) [Patent Document 1] Japanese Laid-open Patent Application Publication No. 2020-61472
SUMMARY
(8) A substrate processing system includes a load-lock module including a plurality of load-lock module stages, a process module including a plurality of process module stages, a vacuum transfer module that connects the load-lock module to the process module, a first transfer device configured to transfer a plurality of substrates from the plurality of load-lock module stages to the plurality of process module stages, the first transfer device being provided in the vacuum transfer module, a second transfer device configured to transfer the plurality of substrates to the plurality of load-lock module stages, and a processor. The processor is configured to perform teaching a position at which the first transfer device receives the plurality of substrates from the load-lock module, teaching a position at which the first transfer device delivers the plurality of substrates to the process module, measuring shift amounts between the plurality of process module stages and the plurality of substrates mounted thereon, and correcting positions at which the second transfer device delivers the plurality of substrates to the plurality of load-lock module stages based on the measured shift amounts.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
(1) FIG. **1** is a plan view illustrating an example configuration of a substrate processing system according to an embodiment;
(2) FIG. **2** is a plan view illustrating an example configuration of the substrate processing system according to the embodiment;
(3) FIG. **3**A to FIG. **3**D are perspective views depicting an example of an operation of mounting a wafer on a stage of a process module;
(4) FIG. **4**A to FIG. **4**D are perspective views depicting an example of the operation of mounting the wafer on the stage of the process module;
(5) FIG. **5** is an example of a flowchart depicting a method of teaching a transfer device in a substrate processing system according to a first embodiment;
(6) FIG. **6** is an example of a flowchart depicting a method of teaching a transfer device in a substrate processing system according to a second embodiment;
(7) FIG. **7** is an example of a plan view depicting the shift amount in each stage of the process module; and
(8) FIG. **8** is an example of a plan view depicting the correction amount in each stage of a load-lock module.
DETAILED DESCRIPTION OF EMBODIMENTS
(9) In the following, embodiments of the present disclosure will be described with reference to the drawings. In each drawing, the same components are indicated by the same reference numerals and overlapping descriptions may be omitted.
(10) <Substrate Processing System>
(11) An example of an overall configuration of a substrate processing system according to the embodiment will be described with reference to FIG. **1** and FIG. **2**. FIG. **1** and FIG. **2** are plan views each illustrating an example configuration of the substrate processing system according to the embodiment. FIG. **1** illustrates an example of a state in which a wafer W is transferred into a process module PM**1**. FIG. **2** illustrates an example of a state before the wafer W is transferred

from a load-lock module LLM. The wafer W is illustrated with dot hatching.
(12) The substrate processing system illustrated in FIG. **1** is a cluster structure (multi-module type) system. The substrate processing system includes process modules PM**1** to PM**6**, a transfer module VTM (a vacuum transfer module), a load-lock module LLM, loader modules LM**1** to LM**2**, load ports LP**1** to LP**4**, and a controller **100**.
(13) The process modules PM**1** to PM**6** are depressurized to a predetermined vacuum atmosphere, and a desired process (an etching process, a deposition process, a cleaning process, an asking process, and the like) is performed on the semiconductor wafer W (hereinafter referred to as the “wafer W”) inside the process modules. The process modules PM**1** to PM**6** are disposed adjacent to the transfer module VTM. The process modules PM**1** to PM**6** and the transfer module VTM communicate by opening and closing gate valves GV**1** to GV**6**. The process module PM**1** includes stages **11** to **14** where a total of four wafers W are mounted in a 2×2 matrix shape in plan view. Similarly, the process modules PM**2** to PM**6** each include stages where four wafers W are mounted. Here, the operation of each section for processing in the process modules PM**1** to PM**6** is controlled by the controller **100**.
(14) The transfer module VTM is depressurized to a predetermined vacuum atmosphere. Additionally, a transfer device ARM**1** that transfers the wafer W is provided inside the transfer module VTM. The transfer device ARM**1** carries in and carries out the wafer W between the process modules PM**1** to PM**6** and the transfer module VTM in accordance with the opening and closing of the gate valves GV**1** to **6**. The transfer device ARM**1** carries in and carries out the wafers W between the load-lock module LLM and the transfer module VTM in accordance with the opening and closing of the gate valve GV**7**. The operation of the transfer device ARM**1** and the opening and closing of the gate valves GV**1** to GV**7** are controlled by the controller **100**.
(15) The transfer device ARM**1** is configured as a multi-joint arm including a base **21**, a first link **22**, a second link **23**, and an end effector **24**. One end of the first link **22** is rotatably attached to the base **21** such that the rotational axis is the up and down direction. Additionally, the base **21** is configured to move the first link **22** in the up and down direction. One end of the second link **23** is rotatably attached to the other end of the first link **22** such that the rotational axis is the up and down direction. The base end of the end effector **24** is rotatably attached to the other end of the second link **23** such that the rotational axis is the up and down direction. At the distal end of the end effector **24**, multiple holders for holding the wafers W are provided. An actuator that drives the lift of the first link **22**, the joint between the base **21** and the first link **22**, the joint between the first link **22** and the second link **23**, and the joint between the second link **23** and the end effector **24** is controlled by the controller **100**.
(16) The end effector **24** is formed in a fork shape having branches on a distal side and has a base end **240** and two blades **241** and **242** (branches of the fork shape) extending from the base end **240**. The blades **241** and **242** extend in the same direction from the base end **240** and are formed at the same height. The blade **241** has holders **243** and **244** that hold multiple wafers W along the longitudinal direction of the blade **241**. The blade **242** has holders **245** and **246** that hold multiple wafers W along the longitudinal direction of the blade **242**. As described, the four wafers W held by the end effector **24** are held at the same height (on the same plane).
(17) Additionally, sensors S**0** to S**7** that detect the wafers W are provided inside the transfer module VTM. The sensor S**0** detects whether the wafer W is held by the holders **243** to **246** in a state in which the end effector **24** of the transfer device ARM**1** is positioned at a reference position (see FIG. **2**). The sensor S**1** detects whether the wafer W is held and detects the eccentricity amount of the held wafer W when the transfer device ARM**1** transfers the wafer W into the process module PM**1** or when the transfer device ARM**1** transfers the wafer W from the process module PM**1**. Here, the detection method of the sensor S**1** will be described later with reference to FIGS. **3**A to **3**D. Similarly, the sensors S**2** to S**6** each detect whether the wafer W is held and the eccentricity amount of the held wafer W when the transfer device ARM**1** transfers the wafer W into the process

modules PM**2** to PM**6** or the transfer device ARM**1** transfers the wafer from the process modules PM**2** to PM**6**. The sensor S**7** detects whether the wafer W is held and detects the eccentricity amount of the held wafer W when the transfer device ARM**1** transfers the wafer W into the load-lock module LLM or when the transfer device ARM**1** transfers the wafer W from the load-lock module LLM. An optical passing sensor can be used for the sensors S**0** to S**7**, for example. The values detected by the sensors S**0** to S**7** are input to the controller **100**.

(18) The load-lock module LLM is provided between the transfer module VTM and the loader modules LM**1** and LM**2**. The load-lock module LLM is configured to switch between an ambient air atmosphere and a vacuum atmosphere. The load-lock module LLM and the transfer module VTM in the vacuum atmosphere communicate with each other by opening and closing the gate valve GV**7**. The load-lock module LLM and the loader module LM**1** in the ambient air atmosphere communicate with each other by opening and closing a door valve GV**8**. The load-lock module LLM and the loader module LM**2** in the ambient air atmosphere communicate with each other by opening and closing a door valve GV**9**. The load-lock module LLM includes stages **31** to **34** where a total of four wafers W are mounted in a 2×2 matrix shape in plan view. Additionally, the arrangement of the stages **11** to **14** of the process modules PM**1** to PM**6** and the arrangement of the stages **31** to **34** of the load-lock module LLM are the same. Here, the switching between the vacuum atmosphere and the ambient air atmosphere in the load-lock module LLM is controlled by the controller **100**.

(19) The loader modules LM**1** and LM**2** have the ambient air atmosphere in which, for example, a clean air downflow is formed. Additionally, a transfer device ARM**2** that transfers the wafer W is provided inside the loader module LM**1**. The transfer device ARM**2** carries in and carries out the wafer W between the load-lock module LLM and the loader module LM**1** in accordance with the opening and closing of the door valve GV**8**. Similarly, a transfer device ARM**3** that transfers the wafer W is provided inside the loader module LM**2**. The transfer device ARM**3** carries in and carries out the wafer W between the load-lock module LLM and the loader module LM**2** in accordance with the opening and closing of the door valve GV**9**. Additionally, a delivery section (not illustrated) where the wafer W is mounted is provided on the lower side of the load-lock module LLM. The transfer devices ARM**2** and ARM**3** can deliver the wafer W through the delivery section. Here, the operations of the transfer devices ARM**2** and ARM**3** and the opening and closing of the door valves GV**8** and GV**9** are controlled by the controller **100**.

(20) The transfer device ARM**2** is configured as a multi-joint arm including a base **41**, a first link **42**, a second link **43**, and an end effector **44**. One end of the first link **42** is rotatably attached to the base **41** such that the rotational axis is the up and down direction. Additionally, the base **41** is configured to move the first link **42** in the up and down direction. One end of the second link **43** is rotatably attached to the other end of the first link **42** such that the rotational axis is the up and down direction. The base end of the end effector **44** is rotatably attached to the other end of the second link **43** such that the rotational axis is the up and down direction. At the distal end of the end effector **44**, a holder **441** that holds the wafer W is provided. An actuator that drives the lift of the first link **42**, the joint between the base **41** and the first link **42**, the joint between the first link **42** and the second link **43**, and the joint between the second link **43** and the end effector **44** is controlled by the controller **100**. The transfer device ARM**3** is configured as a multi-joint arm substantially the same as the transfer device ARM**2**.

(21) Load ports LP**1** and LP**2** are provided on the wall of the loader module LM**1**. Additionally, load ports LP**3** and LP**4** are provided on the wall of the loader module LM**2**. A carrier C in which the wafer W is accommodated or an empty carrier C is attached to the load ports LP**1** to LP**4**. For example, a front opening unified pod (FOUP) or the like may be used as the carrier C.

(22) The transfer device ARM**2** can hold the wafer W accommodated in the load port LP**1** or LP**2** with the holder **441** of the transfer device ARM**2** and take out the wafer W. Additionally, the transfer device ARM**2** can accommodate the wafer W held in the holder **441** in the load port LP**1** or

LP**2**. Similarly, the transfer device ARM**3** can hold the wafer W accommodated in the load port LP**3** or LP**4** with the holder of the transfer device ARM**3** and take out the wafer W. Additionally, the transfer device ARM**3** can accommodate the wafer W held in the holder in the load port LP**3** or LP**4**.

(23) The controller **100** includes a central processing unit (CPU), a read only memory (ROM), a random access memory (RAM), and a hard disk drive (HDD). A storage area of the controller **100** is not limited to the HDD and the controller **100** may include another storage area such as a solid state drive (SSD). A recipe in which process procedures, process conditions, and transfer conditions are set is stored in the storage area, such as the HDD, the RAM, and the like.

(24) The CPU controls the processing of the wafer W in each process module PM according to the recipe and controls the transfer of the wafer W. The HDD or RAM may store programs for performing the processing of the wafer W and the transfer of the wafer W in each process module PM. The program may be provided in a storage medium or may be provided by an external device through a network.

(25) <Operation of the Substrate Processing System>

(26) Next, an example of an operation of the substrate processing system will be described. Here, as the example of the operation of the substrate processing system, an operation, in which the wafer W accommodated in the carrier C attached to the load port LP**1** is processed in the process module PM**1** and the wafer W is accommodated in the empty carrier C attached to the load port LP**3**, will be described. Here, at the start of the operation, the gate valves GV**1** to GV**7** and the door valves GV**8** and GV**9** are closed and the inside of the load-lock module LLM is the ambient air atmosphere.

(27) The controller **100** controls the transfer device ARM**2** to take out a first wafer W from the carrier C of the load port LP**1** and place the first wafer W on the delivery section (not illustrated). Additionally, the controller **100** controls the transfer device ARM**2** to take out a second wafer W from the carrier C of the load port LP**1** and place the second wafer W on the delivery section (not illustrated).

(28) The controller **100** opens the door valves GV**8** and GV**9**. The controller **100** controls the transfer device ARM**3** to take out the first wafer W placed in the delivery section (not illustrated) and mount the first wafer W on the stage **31** of the load-lock module LLM. In addition, the controller **100** controls the transfer device ARM**2** to take out a third wafer W from the carrier C of the load port LP**1** and mount the third wafer W on the stage **33** of the load-lock module LLM.

(29) Further, the controller **100** controls the transfer device ARM**3** to take out the second wafer W placed in the delivery section (not illustrated) and mount the second wafer W on the stage **32** of the load-lock module LLM. In addition, the controller **100** controls the transfer device ARM**2** to take out a fourth wafer W from the carrier C of the load port LP**1** and mount the fourth wafer W on the stage **34** of the load-lock module LLM. Here, when the controller mounts the wafers W on the stages **31** to **34**, the controller **100** controls the transfer devices ARM**2** and ARM**3** based on corrected teaching positions (i.e., corrected instructed positions) (S**104** and S**206**), which will be described later, to mount the wafers W on the stages **31** to **34**. Four wafers W are mounted on the stages **31** to **34** of the load-lock module LLM, and when the transfer devices ARM**2** and ARM**3** retreat from the load-lock module LLM, the controller **100** closes the door valves GV**8** and GV**9**.

(30) The controller **100** controls an exhaust device (not illustrated) of the load-lock module LLM to exhaust air in the module and switch from the ambient air atmosphere to the vacuum atmosphere in the load-lock module LLM.

(31) The controller **100** controls the transfer device ARM**1** to move the end effector **24** to the reference position. The controller **100** checks that the wafer W is not held in the blade **241** or **242** with the sensor S**0**. The controller **100** opens the gate valve GV**7**. The controller **100** controls the transfer device ARM**1** to insert the blades **241** and **242** of the end effector **24** into the load-lock module LLM to reach the teaching position in the load-lock module LLM that is set in advance.

The controller **100** controls the transfer device ARM**1** to hold the wafers W mounted on the stages **31** to **34** of the load-lock module LLM and transfer the wafers W to the transfer module VTM. Here, when receiving the wafers W from the stages **31** to **34**, the controller **100** controls the transfer device ARM**1** based on the teaching position (S**101** and S**201**), which will be described later, and receives the wafers W from the stages **31** to **34**. The arrangement of the stages **31** to **34** of the load-lock module LLM is the same as the arrangement of the stages **11** to **14** of the process module PM**1**. Therefore, the arrangement of the wafers W held in the blades **241** and **242** of the end effector **24** is substantially the same as the arrangement of the stages **11** to **14** of the process module PM**1**. When the end effector **24** retreats from the load-lock module LLM, the controller **100** closes the gate valve GV**7**.
(32) The controller **100** opens the gate valve GV**1**. The controller **100** controls the transfer device ARM**1** to insert the blades **241** and **242** of the end effector **24** into the process module PM**1** to the teaching position in the process module PM**1** that is set in advance and mount the held wafers W on the stages **11** to **14** of the process module PM**1**. Here, when mounting the wafers W on the stages **11** to **14**, the controller **100** controls the transfer device ARM**1** based on the teaching position (S**102** and S**205**), which will be described later, to mount the wafers W on the stages **11** to **14**. When the end effector **24** retreats from the process module PM**1**, the controller **100** closes the gate valve GV**1**.
(33) The controller **100** controls the process module PM**1** to perform a desired process on the wafers W.
(34) When the processing of the wafers W is completed, the controller **100** opens the gate valve GV**1**. The controller **100** controls the transfer device ARM**1** to insert the blades **241** and **242** of the end effector **24** into the process module PM**1** to the teaching position in the process module PM**1** that is set in advance. The controller **100** controls the transfer device ARM**1** to hold the wafers W mounted on the stages **11** to **14** of the process module PM**1** and transfer the wafers W to the transfer module VTM. When the end effector **24** retreats from the process module PM**1**, the controller **100** closes the gate valve GV**1**.
(35) The controller **100** opens the gate valve GV**7**. The controller **100** controls the transfer device ARM**1** to insert the blades **241** and **242** of the end effector **24** into the load-lock module LLM to the teaching position of the load-lock module LLM that is set in advance, and mount the held wafers W on the stages **31** to **34** of the load-lock module LLM. When the end effector **24** retreats from the load-lock module LLM, the controller **100** closes the gate valve GV**7**.
(36) The controller **100** controls a suction device (not illustrated) of the load-lock module LLM to supply, for example, clean air into the module and switch from the vacuum atmosphere to the ambient air atmosphere in the load-lock module LLM.
(37) The controller **100** opens the door valves GV**8** and GV**9**. The controller **100** controls the transfer device ARM**3** to take out the first wafer W mounted on the stage **31** of the load-lock module LLM and accommodate the first wafer W in the carrier C of the load port LP**3**. In addition, the controller **100** controls the transfer device ARM**2** to take out the third wafer W mounted on the stage **33** of the load-lock module LLM and place the third wafer W in the delivery section (not illustrated).
(38) Further, the controller **100** controls the transfer device ARM**3** to take out the second wafer W mounted on the stage **32** of the load-lock module LLM and accommodate the second wafer W in the carrier C of the load port LP**3**. In addition, the controller **100** controls the transfer device ARM**2** to take out the fourth wafer W mounted on the stage **34** of the load-lock module LLM and place the fourth wafer W in the delivery section (not illustrated). When four wafers W are taken out from the stages **31** to **34** of the load-lock module LLM and the transfer devices ARM**2** and ARM**3** retreat from the load-lock module LLM, the controller **100** closes the door valves GV**8** and GV**9**.
(39) The controller **100** controls the transfer device ARM**3** to take out the third wafer W from the delivery section (not illustrated) and accommodate the third wafer W in the carrier C of the load

port LP**3**. Additionally, the controller **100** controls the transfer device ARM**3** to take out the fourth wafer W from the delivery section (not illustrated) and accommodate the fourth wafer W in the carrier C of the load port LP**3**.
(40) An example, in which the wafer W is transferred into the process module PM**1** and is transferred from the process module PM**1**, has been described above. However, the wafer W may be similarly transferred into and from the process modules PM**2** to PM**6**. Additionally, the wafer W processed in the process module PM**1** may be transferred into the process module PM**2**, for example, and the wafer W may be further processed in the process module PM**2**.
(41) <Operation of Mounting the Wafer W in the Process Module PM**1**>
(42) Next, an example of the operation of mounting the wafers W held by the transfer device ARM**1** on the stages **11** to **14** of the process module PM**1** will be further described with reference to FIGS. **3**A to **3**D and FIGS. **4**A to **4**D. FIGS. **3**A to **3**D and FIGS. **4**A to **4**D are perspective views depicting an example of the operation of mounting the wafers W on the stages **11** to **14** of the process module PM**1**. Here, in FIGS. **3**A to **3**D and FIGS. **4**A to **4**D, only the end effector **24**, the stages **11** to **14**, the sensor S**1**, and the wafers W are illustrated, and other configurations are not illustrated. Additionally, the following description assumes that a direction in which the end effector **24** is inserted into the process module PM**1** is the forward direction, and a direction in which the end effector **24** is removed from the process module PM**1** is the backward direction.
(43) As illustrated in FIG. **3**A, the controller **100** controls the actuator of each joint of the transfer device ARM**1** to move the end effector **24** so that the stages **31** to **34** are positioned in the extending direction of the blades **241** and **242**.
(44) Here, the sensor S**1** includes sensor units **51** and **52**. The number of sensor units is equal to the number of blades of the end effector **24**. The sensor unit **51** is disposed on a path in which the blade **241** enters the process module PM**1**. Additionally, the sensor unit **52** is disposed on a path in which the blade **242** enters the process module PM**1**.
(45) The sensor unit **51** includes two sensor elements **51***a* and **51***b* that are disposed spaced apart. The sensor elements **51***a* and **51***b* are, for example, optical passing sensors each including a light emitting unit and a light receiving unit. The sensor elements **51***a* and **51***b* detect whether there is an object to be detected by irradiating light from the light emitting unit and detecting reflected light from the object to be detected at the light receiving unit. The space between the sensor element **51***a* and the sensor element **51***b* is wider than the width of the blade **241** and narrower than the diameter of the wafer W. Similarly, the sensor unit **52** also includes two sensor elements **52***a* and **52***b*.
(46) As illustrated in FIG. **3**B, the controller **100** controls the actuator of each joint of the transfer device ARM**1** to move forward the end effector **24**. At this time, the blade **241** passes between the sensor element **51***a* and the sensor element **51***b* in top view. When the holder **244** of the blade **241** positions over the sensor unit **51**, the sensor elements **51***a* and **51***b* of the sensor unit **51** detect the wafer W, so that the controller **100** can determine whether there is the wafer W in the holder **244** based on the value detected by the sensor unit **51**. Similarly, when the holder **246** positions over the sensor unit **52**, the sensor elements **52***a* and **52***b* of the sensor unit **52** detect the wafer W, so that the controller **100** can determine whether there is a wafer W in the holder **246** based on the value detected by the sensor unit **52**.
(47) Additionally, the controller **100** acquires a position at which the end effector **24** is situated when the sensor element **51***a* starts detecting the wafer W, a position at which the end effector **24** is situated when the sensor element **51***a* stops detecting the wafer W, a position at which the end effector **24** is situated when the sensor element **51***b* starts detecting the wafer W, and a position at which the end effector **24** is situated when the sensor element **51***b* stops detecting the wafer W. The controller **100** can detect a position of the wafer W held in the holder **244** based on position information about these four positions. The controller **100** can detect the shift between the reference point of the holder **244** and the center of the wafer W held in the holder **244** (the eccentricity amount) based on the value detected by the sensor unit **51**. Similarly, the controller **100**

can detect the shift between the reference point of the holder **246** and the center of the wafer W held in the holder **246** (the amount of eccentricity) based on the value detected by the sensor unit **52**.
(48) As illustrated in FIG. **3**C, the controller **100** controls the actuator of each joint of the transfer device ARM**1** to further move forward the end effector **24**. At this time, when the holder **243** of the blade **241** positions over the sensor unit **51**, the sensor elements **51***a* and **51***b* of the sensor unit **51** detect the wafer W, so that the controller **100** can determine whether there is the wafer W in the holder **243** based on the value detected by the sensor unit **51**. Similarly, when the holder **245** positions over the sensor unit **52**, the sensor elements **52***a* and **52***b* of the sensor unit **52** detect the wafer W, so that the controller **100** can determine whether there is the wafer W in the holder **245** based on the value detected by the sensor unit **52**.
(49) Additionally, the controller **100** can detect the shift between the reference point of the holder **243** and the center of the wafer W held in the holder **243** (the eccentricity amount) based on the value detected by the sensor unit **51**. Similarly, the controller **100** can detect the shift between the reference point of the holder **245** and the center of the wafer W held in the holder **245** (the eccentricity amount) based on the value detected by the sensor unit **52**.
(50) As illustrated in FIG. **3**D, the controller **100** controls the actuator of each joint of the transfer device ARM**1** to further move forward the end effector **24**. Additionally, based on the position shift of the wafer W that is detected by the sensor S**1**, the movement trajectory to be observed until the operation completion of the transfer device ARM**1** is corrected, and the wafer W is transferred. Thus, the wafers W held in the holders **243** to **246** are positioned over the stages **11** to **14**.
(51) Here, the stages **11** to **14** include lift pins **11***a* to **14***a*. The lift pins **11***a* and **12***a* are disposed at positions different from a position through which the blade **241** passes in top view. Additionally, the lift pins **13***a* and **14***a* are disposed at positions different from a position through which the blade **242** passes. Thus, as illustrated in FIG. **4**A, when the lift pins **11***a* to **14***a* are raised, the lift pins **11***a* to **14***a* do not contact the blades **241** and **242** and lift four wafers W held in the end effector **24**. Here, four wafers W are held at the same height in the end effector **24** because the heights of the blades **241** and **242** are equal. Thus, the lift pins **11***a* to **14***a* may be configured to be raised simultaneously by one lifter.
(52) Next, the controller **100** controls the actuator of each joint of the transfer device ARM**1** to move backward the end effector **24**. Here, as illustrated in FIG. **4**B, when the end effector **24** is at the same position as in FIG. **3**C, it is checked that the sensor S**1** does not detect the wafer W. That is, the controller **100** checks that there are no wafers W in the holders **243** and **245** based on the values detected by the sensor S**1**. Here, in FIG. **4**B and FIG. **4**C, the positions where the wafers W were placed are illustrated by dotted lines.
(53) The controller **100** then controls the actuator of each joint of the transfer device ARM**1** to further move backward the end effector **24**. Here, as illustrated in FIG. **4**C, when the end effector **24** is at the same position as in FIG. **3**B, it is checked that the sensor S**1** does not detect the wafer W. That is, the controller **100** checks that there are no wafers W in the holders **244** and **246** based on the values detected by the sensor S**1**.
(54) As illustrated in FIG. **4**D, by moving backward the end effector **24**, the end effector **24** retreats from the process module PM**1**. Subsequently, the wafers W are mounted on the stages **11** to **14** by lowering the lift pins **11***a* to **14***a*.
(55) An example in which the wafer W is transferred into the process module PM**1** has been described above. However, when the wafer W is transferred from the process module PM**1**, it is only required that the steps illustrated in FIGS. **3**A to **4**D are reversed, and the description thereof is omitted. Additionally, the same will apply when the wafer W is transferred into the process modules PM**2** to PM**6** or the load-lock module LLM, and the overlapping description is omitted.
(56) <Teaching Method>
(57) Next, a method of teaching the transfer devices ARM**1** to ARM**3** will be described. FIG. **5** is

an example of a flowchart depicting a method of teaching the transfer devices ARM**1** to ARM**3** in a substrate processing system according to a first embodiment. In the present specification, "teaching the transfer device" indicates determining a position of the end effector and instructing the determined position to the transfer device.
(58) In step S**101**, the controller **100** teaches the transfer devices ARM**1** to ARM**3** with respect to the load-lock module LLM. That is, the controller **100** determines positions of the end effectors of the transfer devices ARM**1** to ARM**3** with respect to the load-lock module LLM and instructs the determined positions to the transfer devices ARM**1** to ARM**3**.
(59) Here, the controller **100** teaches the position of the end effector **44** of the transfer device ARM**3** when the transfer device ARM**3** delivers the wafer W to the stage **31** of the load-lock module LLM or when the transfer device ARM**3** receives the wafer W from the stage **31** of the load-lock module LLM. For example, a wafer-shaped inspection device with a camera (not illustrated) is mounted on the end effector **44** and transferred over the stage **31**, and the controller **100** teaches a position such that the center of the wafer-shaped inspection device matches with the center of the stage **31**.
(60) Similarly, the controller **100** teaches the position of the end effector **44** of the transfer device ARM**3** when the transfer device ARM**3** delivers the wafer W to the stage **32** of the load-lock module LLM or when the transfer device ARM**3** receives the wafer W from the stage **32** of the load-lock module LLM. Additionally, the controller **100** teaches the position of the end effector **44** of the transfer device ARM**2** when the transfer device ARM**2** delivers the wafer W to the stage **33** of the load-lock module LLM or when the transfer device ARM**2** receives the wafer W from the stage **33** of the load-lock module LLM. Additionally, the controller **100** teaches the position of the end effector **44** of the transfer device ARM**2** when the transfer device ARM**2** delivers the wafer W to the stage **34** of the load-lock module LLM or when the transfer device ARM**2** receives the wafer W from the stage **34** of the load-lock module LLM.
(61) Additionally, the controller **100** teaches the position of the end effector **24** of the transfer device ARM**1** when the transfer device ARM**1** receives the wafer W from the stages **31** to **34** of the load-lock module LLM or when the transfer device ARM**1** delivers the wafer W to the stages **31** to **34** of the load-lock module LLM. For example, wafer-shaped inspection devices with cameras (not illustrated) are mounted on the holders **243** to **246** of the end effector **24** and transferred over the stages **31** to **34**, and the controller **100** teaches a position such that the centers of the wafer-shaped inspection devices match with or are close to the centers of the stages **31** to **34**.
(62) In step S**102**, the controller **100** teaches the transfer device ARM**1** with respect to the process module PM**1**. That is, the controller **100** determines a position of the end effector **24** of the transfer device ARM**1** with respect to the process module PM**1** and instructs the determined position to the transfer device ARM**1**.
(63) Here, the controller **100** teaches the position of the end effector **24** of the transfer device ARM**1** when the transfer device ARM**1** delivers the wafers W to the stages **11** to **14** of the process module PM**1** or when the transfer device ARM**1** receives the wafers W from the stages **11** to **14** of the process module PM**1**. For example, wafer-shaped inspection devices with cameras (not illustrated) are mounted on the holders **243** to **246** of the end effectors **24** and transferred over the stages **11** to **14**, and the controller **100** teaches a position such that the centers of the wafer-shaped inspection devices match with or are close to the centers of the stages **11** to **14**.
(64) In step S**103**, the controller **100** measures the shift amounts of the wafers W in the process module PM**1** when the wafers W are transferred from the load-lock module LLM to the process module PM**1**.
(65) Here, the positions of the stages **11** to **14** have individual errors with respect to the design values. Thus, when the wafers W are mounted on the stages **11** to **14**, a shift is generated between the center of each of the stages **11** to **14** and the center of the wafer W mounted thereon.
(66) The controller **100** controls the transfer device ARM**1** to receive four wafers W from the stages

31 to **34** at the teaching position in the load-lock module LLM that is set in step S**101**, and measure the shift amount between the center of each of the stages **11** to **14** and the center of the wafer W mounted thereon when four wafers W are delivered to the stages **11** to **14** at the teaching position in the process module PM**1** that is set in step S**102**. For example, wafer-shaped inspection devices with cameras (not illustrated) are mounted on the stages **31** to **34** and transferred to the stages **11** to **14** by the transfer device ARM**1**, and the shift amount between the center of each of the stages **11** to **14** and the center of the wafer-shaped inspection device mounted thereon is measured.
(67) Here, the method of measuring the shift amounts is not limited thereto. For example, the wafers W are mounted on the stages **11** to **14** such that the centers of the stages **11** to **14** respectively match with the centers of the wafers W. The wafers W are then delivered from the stages **11** to **14** to the holders **243** to **246** of the end effector **24**, and four wafers W are delivered over the sensor S**1**. With this method, by detecting the position of the edge of each of the wafers W and calculating the center position of each of the wafers W, the shift amounts of the respective stages **11** to **14** may be measured.
(68) In step S**104**, the controller **100** corrects the positions (the teaching positions) at which the transfer device ARM**2** or the transfer device ARM**3** delivers the wafers W to the stages **31** to **34** of the load-lock module LLM based on the shift amounts measured in step S**103**.
(69) That is, the position (the teaching position) at which the transfer device ARM**3** delivers the wafer W to the stage **31** of the load-lock module LLM is corrected based on the shift amount in the stage **11**. Here, the position (the teaching position) at which the wafer W is delivered to the stage **31** is corrected such that the shift amount is reduced or is canceled.
(70) Similarly, the position (the teaching position) at which the transfer device ARM**3** delivers the wafer W to the stage **32** of the load-lock module LLM is corrected based on the shift amount in the stage **12**. Additionally, the position (the teaching position) at which the transfer device ARM**2** delivers the wafer W to the stage **33** of the load-lock module LLM is corrected based on the shift amount in the stage **13**. Additionally, the position (the teaching position) at which the transfer device ARM**2** delivers the wafer W to the stage **34** of the load-lock module LLM is corrected based on the shift amount in the stage **14**.
(71) Then, when the transfer device ARM**2** or ARM**3** transfers the wafers W from the carrier C to the process module PM**1**, the wafers W are mounted on the stages **31** to **34** in consideration of the error from the design values in the stages **11** to **14** of the process module PM**1**, and four wafers W mounted on the stages **31** to **34** are transferred to the stages **11** to **14**. This can reduce the error between the center of each of the stages **11** to **14** and the center of the wafer W mounted thereon.
(72) Additionally, the controller **100** stores respective correction values corresponding to the process modules PM**1** to PM**6**. The controller **100** controls the transfer devices ARM**2** or ARM**3** to mount the wafers W to the stages **31** to **34** at positions corrected with correction values corresponding to the process modules PM**1** to PM**6** to which the wafers W are to be transferred. This allows the wafers W to be mounted in accordance with the shift amounts of the stages **11** to **14** in the process modules PM**1** to PM**6**.
(73) Next, another teaching method of the transfer devices ARM**1** to ARM**3** will be described. FIG. **6** is an example of a flowchart illustrating a method of teaching the transfer devices ARM**1** to ARM**3** in a substrate processing system according to a second embodiment.
(74) In step S**201**, the controller **100** teaches the transfer devices ARM**1** to ARM**3** with respect to the load-lock module LLM.
(75) In step S**202**, the controller **100** teaches the transfer device ARM**1** with respect to the process module PM**1**.
(76) In step S**203**, the controller **100** measures the shift amounts of the wafers W in the process module PM**1** when the wafer W is transferred from the load-lock module LLM to the process module PM**1**.
(77) Here, the processing in steps S**201** to S**203** is substantially the same as the processing in steps

S**101** to S**103**, and the overlapping description is omitted.
(78) In step S**204**, the controller **100** calculates a common shift component and individual shift components with respect to the four wafers W mounted in the stages **11** to **14**, based on the shift amounts measured in step S**103**.
(79) Here, the shift amount of each of the stages **11** to **14** will be described with reference to FIG. **7**. FIG. **7** is an example of a plan view depicting the shift amount in each of the stages **11** to **14** of the process module PM**1**.
(80) An actual shift amount **101** in the stage **11** measured in step S**203** is represented by a solid arrow. Similarly, an actual shift amount **102** in the stage **12** is represented by a solid arrow. Additionally, an actual shift amount **103** in the stage **13** is represented by a solid arrow. Additionally, an actual shift amount **104** of the stage **14** is represented by a solid arrow.
(81) Here, the controller **100** calculates a shift component **200** that is common among the shift amounts **101** to **104** and individual shift components **301** to **304** based on the shift amounts **101** to **104** measured in step S**203**. Here, the sum of the common shift component **200** and the individual shift component **301** is the shift amount **101**. The sum of the common shift component **200** and the individual shift component **302** is the shift amount **102**. The sum of the common shift component **200** and the individual shift component **303** is the shift amount **103**. The sum of the common shift component **200** and the individual shift component **304** is the shift amount **104**. The common shift component **200** is represented by a dash-dot-dash arrow. The individual shift components **301** to **304** are represented by dashed arrow.
(82) For example, the controller **100** calculates the common shift component **200** such that the maximum of the individual shift components **301** to **304** is reduced. That is, the common shift component **200** is calculated such that the correction amount in step S**206**, which will be described later, is reduced.
(83) Here, the method of calculating the common shift component **200** and the individual shift components **301** to **304** is not limited thereto.
(84) Returning to FIG. **6**, in step S**205**, the controller **100** corrects the position (the teaching position) at which the transfer device ARM**1** delivers the wafers W to the stages **11** to **14** of the process module **1** based on the common shift component **200** calculated in step S**204**.
(85) That is, the position (the teaching position) at which the transfer device ARM**1** delivers the wafers W to the stages **11** to **14** of the process module PM**1** is corrected based on the common shift component **200**. Here, the delivery position (the teaching position) is corrected to cancel the common shift component **200**.
(86) In step S**206**, the controller **100** corrects the positions (the teaching positions) at which the transfer device ARM**2** or the transfer device ARM**3** delivers the wafers W to the stages **31** to **34** of the load-lock module LLM based on the individual shift components **301** to **304** calculated in step S**204**.
(87) That is, the position (the teaching position) at which the transfer device ARM**3** delivers the wafer W to the stage **31** of the load-lock module LLM is corrected based on the individual shift component **301** in the stage **11**. Here, the position (the teaching position) at which the wafer W is delivered to the stage **31** is corrected to cancel the individual shift component **301**.
(88) Similarly, the position (the teaching position) at which the transfer device ARM**3** delivers the wafer W to the stage **32** of the load-lock module LLM is corrected based on the individual shift component **302** in the stage **12**. Additionally, the position (the teaching position) at which the transfer device ARM**2** delivers the wafer W to the stage **33** of the load-lock module LLM is corrected based on the individual shift component **303** in the stage **13**. Additionally, the position (the teaching position) at which the transfer device ARM**2** delivers the wafer W to the stage **34** of the load-lock module LLM is corrected based on the individual shift component **304** in the stage **14**.
(89) FIG. **8** is an example of a plan view depicting the correction amount in each of the stages **31** to

34 of the load-lock module LLM. A correction amount **401** in the stage **31** is set to cancel the individual shift component **301** illustrated in FIG. **7**. For example, the correction amount **401** is directed opposite to the individual shift component **301** and the absolute value of the correction amount **401** is equal to the absolute value of the individual shift component **301**.

(90) Similarly, a correction amount **402** in the stage **32** is set to cancel the individual shift component **302** illustrated in FIG. **7**. A correction amount **403** in the stage **33** is set to cancel the individual shift component **303** illustrated in FIG. **7**. A correction amount **404** in the stage **34** is set to cancel the individual shift component **304** illustrated in FIG. **7**.

(91) This allows the wafers W to be mounted on the stages **31** and **34** in consideration of the individual shift components **301** and **304** in the stages **11** and **14** of the process module PM**1**, when the transfer device ARM**2** or ARM**3** transfers the wafers W from the carrier C to the process module PM**1**. When the transfer device ARM**1** transfers four wafers W mounted on the stages **31** to **34** to the stages **11** to **14**, the wafers W are mounted on the stages **11** to **14** in consideration of the common shift component **200**. This can reduce the error between the center of each of the stages **11** to **14** and the center of the wafer W mounted thereon.

(92) Additionally, the controller **100** stores the respective correction values corresponding to the process modules PM**1** to PM**6**. The controller **100** controls the transfer devices ARM**2** or ARM**3** to mount the wafers W on the stages **31** to **34** at the positions corrected with the correction values corresponding to the process modules PM**1** to PM**6** to which the wafers W are to be transferred. This allows the wafers W to be mounted in accordance with the shift amounts of the stages **11** to **14** in the process modules PM**1** to PM**6**.

(93) Further, according to the method of teaching the transfer devices ARM**1** to ARM**3** in the substrate processing system according to the second embodiment, the shift amount can be divided into the common shift amount used by the transfer device ARM**1** and the individual shift amounts used by the transfer devices ARM**2** and ARM**3**. This can expand the correction allowable range by dividing a shift amount that is greater than the correction allowable range of the transfer devices ARM**1** to ARM**3** into the common shift amount used by the transfer device ARM**1** and the individual shift amounts used by the transfer devices ARM**2** and ARM**3**. Additionally, because the correction amount of each of the transfer devices ARM**1** to ARM**3** can be reduced, a high correction accuracy is maintained thereby.

(94) According to one aspect of the present disclosure, a substrate processing system that transfers a substrate in consideration of a shift of a stage and a method of teaching a transfer device can be provided.

(95) Although the substrate processing system has been described above, the present disclosure is not limited to the above-described embodiments and the like, and various modifications and improvements can be made within the scope of the subject matter of the present disclosure as claimed.

Claims

1. A substrate processing system comprising: a load-lock module including a plurality of load-lock module stages; a process module including a plurality of process module stages; a vacuum transfer module that connects the load-lock module to the process module; a first transfer device including a first arm and configured to transfer a plurality of substrates from the plurality of load-lock module stages to the plurality of process module stages, the first transfer device being provided in the vacuum transfer module; a second transfer device including a second arm and configured to transfer the plurality of substrates to the plurality of load-lock module stages; and a processor configured to perform: teaching a position at which the first transfer device receives the plurality of substrates from the load-lock module; teaching a position at which the first transfer device delivers the plurality of substrates to the process module; measuring shift amounts between the plurality of

process module stages and the plurality of substrates mounted on the plurality of process module stages, the shift amounts being measured after the transferring of the first transfer device; and correcting positions at which the second transfer device delivers the plurality of substrates to the plurality of load-lock module stages based on the measured shift amounts.

2. A substrate processing system comprising: a load-lock module including a plurality of load-lock module stages; a process module including a plurality of process module stages; a vacuum transfer module that connects the load-lock module to the process module; a first transfer device including a first arm and configured to transfer a plurality of substrates from the plurality of load-lock module stages to the plurality of process module stages, the first transfer device being provided in the vacuum transfer module; a second transfer device including a second arm and configured to transfer the plurality of substrates to the plurality of load-lock module stages; and a processor configured to perform: teaching a position at which the first transfer device receives the plurality of substrates from the load-lock module; teaching a position at which the first transfer device delivers the plurality of substrates to the process module; measuring a first shift amount and a second shift amount between the plurality of process module stages and the plurality of substrates mounted on the plurality of process module stages; correcting the position at which the first transfer device delivers the plurality of substrates to the process module based on a first shift component; and correcting positions at which the second transfer device delivers the plurality of substrates to the plurality of load-lock module stages based on a second shift component and a third shift component, wherein the measured first shift amount is a sum of the first shift component and the second shift component and the measured second shift amount is a sum of the first shift component and the third shift component.

3. A method of teaching a transfer device in a substrate processing system including a load-lock module including a plurality of load-lock module stages, a process module including a plurality of process module stages, a vacuum transfer module that connects the load-lock module to the process module, a first transfer device including a first arm and configured to transfer a plurality of substrates from the plurality of load-lock module stages to the plurality of process module stages, the first transfer device being provided in the vacuum transfer module, a second transfer device including a second arm and configured to transfer the plurality of substrates to the plurality of load-lock module stages, and a processor, the method comprising: teaching a position at which the first transfer device receives the plurality of substrates from the load-lock module; teaching a position at which the first transfer device delivers the plurality of substrates to the process module; measuring shift amounts between the plurality of process module stages and the plurality of substrates mounted on the plurality of process module stages, the shift amounts being measured after the transferring of the first transfer device; and correcting load-lock module positions at which the second transfer device delivers the plurality of substrates to the plurality of load-lock module stages based on the measured shift amounts.

4. The method as claimed in claim 3, wherein the correcting of the load-lock module positions includes correcting a position in each of the plurality of load-lock module stages based on an amount of the shift amounts in a corresponding stage among the plurality of process module stages.

5. The method as claimed in claim 3, further comprising correcting a process module position at which the first transfer device delivers the plurality of substrates to the process module, wherein the measured shift amounts include a first shift amount and a second shift amount, wherein the correcting of the process module position includes correcting based on a first shift component, wherein the correcting of the load-lock module positions includes correcting positions in the plurality of load-lock module stages based on a second shift component and a third shift component, and wherein the first shift amount is a sum of the first shift component and the second shift component and the second shift amount is a sum of the first shift component and the third shift component.