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SUBSTRATE HOLDING DEVICE, SUBSTRATE PROCESSING APPARATUS AND SUBSTRATE HOLDING METHOD

Abstract

A substrate holding device includes: a mounting table having a mounting surface on which a substrate is to be mounted; an up-down unit configured to mount the substrate on the mounting surface by moving down a plurality of support pins supporting the substrate from below; a suction unit configured to suck and hold a peripheral part of the substrate from below using a suction pad; a positioning unit configured to position the substrate by abutting on an end surface of the substrate supported by the plurality of support pins at a positioning position separated upward from the suction pad; and a controller configured to control the up-down unit, the suction unit, the up-down unit and the positioning unit. The substrate positioned by the positioning unit is mounted on the mounting surface and then held in suction by the suction unit.

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Background/Summary

CROSS REFERENCE TO RELATED APPLICATION
[0001] The disclosure of Japanese Patent Application No. 2024-24277 filed on Feb. 21, 2024 including specification, drawings and claims is incorporated herein by reference in its entirety.
BACKGROUND OF THE INVENTION
1. Field of the Invention
[0002] The present invention relates to a substrate holding technique of holding substrates on mounting tables that are glass substrates for FPDs such as liquid crystal display devices or organic EL display devices, semiconductor wafers, glass substrates for photomasks, substrates for color filters, substrates for recording disks, substrates for solar cells, substrates for precision electronic devices such as substrates for electronic paper, and substrates for semiconductor packages (these substrates will hereinafter be called “substrates” simply), and a substrate processing technique of applying processing liquids to the substrates held on the mounting tables by supplying the processing liquids from slit nozzles.
2. Description of the Related Art
[0003] Known examples of a substrate processing apparatus include a coating device that applies a processing liquid to a substrate by ejecting the processing liquid to the substrate from a slit nozzle having a slit-like ejection opening while moving the slit nozzle relative to the substrate. As an example, Japanese Patent Application Laid-Open No. 2013-192980 shows an apparatus that applies a processing liquid to a substrate while moving a slit nozzle above a stage surface (corresponding to an example of a “mounting surface” of the present invention) of a stage with the substrate kept held on the stage surface. This apparatus includes a suction cup (corresponding to an example of a “suction pad” of the present invention) provided in the vicinity of a surface of the stage and used for holding a lower surface of a corner of the substrate under suction. The suction cup is connected to an exhaust unit such as a vacuum pump or an exhaust fan. Thus, by exhausting air via the suction cup, the lower surface of the corner of the substrate is held under suction by the suction cup. Then, the processing liquid ejected from the slit nozzle is applied to the substrate held under suction by the suction cup.
SUMMARY OF INVENTION
[0004] A position for mounting the substrate on the stage surface is set in advance. Deviation of the substrate from the mounting position results in the failure to apply the processing liquid favorably. In response to this, incorporating a unit such as a positioning unit or a position adjusting mechanism into the substrate processing apparatus has been suggested. This unit is to adjust the position of the substrate before the substrate is held under suction by the suction cup. As an example, the invention shown in Japanese Patent Application Laid-Open No. 2017-112197 is available as the unit including the positioning unit. The position adjusting mechanism shown therein has a plurality of alignment pins. These alignment pins are provided in such a manner as to surround a substrate supported from below by a suction cup. Each of the alignment pins is horizontally movable toward the substrate. When the alignment pins move toward the substrate and abut on a peripheral edge of the substrate, the substrate is located in a position set in advance (alignment process).

[0005] Simply combining the invention shown in Japanese Patent Application Laid-Open No. 2013-192980 and the invention shown in Japanese Patent Application Laid-Open No. 2017-112197 described above causes a problem as follows. During the positioning process described above, each suction cup is in contact with the substrate. Hence, the substrate rubs against the suction cup when the substrate is moved horizontally by the alignment pins. This horizontal movement causes dust generation from the suction cup and wear of the suction cup, leading to quality reduction in the substrate process.
[0006] The present invention has been made in view of the foregoing problem. In a substrate holding device and a substrate processing apparatus using the substrate holding device that hold a substrate under suction on a mounting table using a suction pad while the substrate is located in a predetermined position relative to the mounting table, the present invention is intended to prevent generation of dust from the suction pad and wear of the suction pad.
[0007] A first aspect of the invention is a substrate holding device. The device comprises: a mounting table having a mounting surface on which a substrate is to be mounted; an up-down unit configured to mount the substrate on the mounting surface by moving down a plurality of support pins supporting the substrate from below; a suction unit configured to suck and hold a peripheral part of the substrate from below using a suction pad; a positioning unit configured to position the substrate by abutting on an end surface of the substrate supported by the plurality of support pins at a positioning position separated upward from the suction pad; and a controller configured to control the up-down unit, the suction unit, and the positioning unit so as to cause the up-down unit to mount the substrate on the mounting surface and to cause the suction unit to hold the substrate under suction while the substrate is positioned by the positioning unit.
[0008] A second aspect of the invention is a substrate processing apparatus. The apparatus comprises: the substrate holding device; and a slit nozzle configured to apply a processing liquid to a surface of the substrate by moving relative to the substrate in a horizontal direction while the substrate is mounted on the mounting surface and is held under suction on the mounting table by the suction pad.
[0009] A third aspect of the invention is a substrate holding method. The method comprises: (a) sucking and holding a substrate on a mounting surface of a mounting table using a suction pad of a suction unit; (b) after the operation (a), positioning the substrate above the mounting surface and the suction pad by causing a positioning member to abut on an end surface of the substrate while supporting the substrate from below using a plurality of support pins; and (c) after the operation (b), mounting the substrate on the mounting surface by moving down the plurality of support pins.
[0010] According to the invention having the foregoing configuration, while the substrate is supported from below by the plurality of support pins in the positioning position separated upward from the suction pad, the positioning member abuts on the end surface of the substrate. By doing so, the substrate is positioned in the horizontal direction. During implementation of this positioning process, the substrate is moved in the horizontal direction while the substrate is a posture of not abutting on the suction pad. After being subjected to the positioning process, the substrate is mounted on the mounting surface by the up-down unit and is held under suction by the suction unit.
[0011] As described above, according to the present invention, while generation of dust from the suction pad and wear of the suction pad are prevented, it is possible to hold the substrate under suction on the mounting table using the suction pad with the substrate located in a predetermined position relative to the mounting table.
[0012] All of a plurality of constituent elements of each aspect of the present invention described above are not essential and some of the plurality of constituent elements can be appropriately changed, deleted, replaced by other new constituent elements or have limited contents partially deleted in order to solve some or all of the aforementioned problems or to achieve some or all of effects described in this specification. Further, some or all of technical features included in one

aspect of the present invention described above can be combined with some or all of technical features included in another aspect of the present invention described above to obtain one independent form of the present invention in order to solve some or all of the aforementioned problems or to achieve some or all of the effects described in this specification.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0013] FIG. **1** schematically shows an entire configuration of a coating device corresponding to an embodiment of a substrate processing apparatus according to the present invention.

[0014] FIG. **2** is a plan view of a principal part of the substrate holding mechanism viewed from above.

[0015] FIG. **3** schematically shows the configuration of the substrate holding mechanism.

[0016] FIG. **4** is a flowchart showing an example of a substrate holding process performed by the substrate processing apparatus in FIG. **1**.

[0017] FIG. **5** is a flowchart showing a procedure of temporary correction on the substrate taken by the substrate holding mechanism in FIG. **2**.

[0018] FIGS. **6**A and **6**C to **6**E are motion explanatory views showing motions conducted according to the flowchart in FIG. **4**.

[0019] FIG. **6**B is a motion explanatory view showing a motion conducted according to the flowchart in FIG. **5**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0020] FIG. **1** schematically shows an entire configuration of a coating device corresponding to an embodiment of a substrate processing apparatus according to the present invention. In FIG. **1** and each of the subsequent drawings, to clearly show a relationship in terms of direction between the drawings, an XYZ orthogonal coordinate system is given in appropriate cases where a vertical direction is represented as a Z direction and a horizontal plane is represented as an XY plane. In the drawings, the dimension of each part or the number of suck parts is drawn in an exaggerated or simplified manner, as necessary.

[0021] A substrate processing apparatus **100** includes a substrate holding mechanism **200** corresponding to an example of a “substrate holding device” according to the present invention. A controller **10** controls each part of the substrate processing apparatus **100**. As a result, while a substrate S is held by the substrate holding mechanism **200**, a slit nozzle **1** moves in the X direction relative to the substrate S to apply a processing liquid to a surface Sa of the substrate S. Specifically, the substrate processing apparatus **100** is an apparatus called a slit coater. Photoresist liquids, pigments for color filters, polyimide precursors, silicon agents, nanometal inks, or various types of paste or slurry processing liquids containing conductive materials are available as the processing liquid, for example. The substrate S is a glass substrate having a rectangular shape in a plan view. The substrate S as a coating target is applicable to various types of substrates such as rectangular glass substrates, semiconductor substrates, flexible substrates for film liquid crystal, substrates for photomasks, substrates for color filters, substrates for solar cells, substrates for organic electroluminescence (EL), and substrates for semiconductor packages. In the present specification, of both main surfaces of the substrate S, “the surface Sa of the substrate S” means a main surface to be coated with the processing liquid.

[0022] In the substrate processing apparatus **100**, a stage **3** corresponding to one of constituting elements of the substrate holding mechanism **200** is arranged on a base **2**. The substrate S is to be mounted on an upper surface of the stage **3** (hereinafter called a “mounting surface **31**”) and is to be held under suction thereon. The configuration and motion of the substrate holding mechanism **200** will be described later in detail.

[0023] The slit nozzle **1** is arranged above the stage **3**. The slit nozzle **1** has a slit-like ejection opening extending in the Y direction, and is capable of ejecting the processing liquid from the ejection opening toward the surface Sa of the substrate S held on the stage **3**. The substrate processing apparatus **100** is provided with a nozzle moving unit **4** that moves the slit nozzle **1** back and forth in the X direction above the stage **3**. The nozzle moving unit **4** includes a nozzle support **41** having a bridge structure extending transversely in the Y direction above the stage **3** to support the slit nozzle **1**, and a nozzle drive mechanism **42** that moves the nozzle support **41** horizontally in the X direction.

[0024] The nozzle support **41** includes a fixing member **41***a* to which the slit nozzle **1** is fixed, and two up-down units **41***b* that move the fixing member **41***a* up and down while supporting the fixing member **41***a*. The fixing member **41***a* is a rod-like member extending lengthwise in the Y direction and having a rectangular sectional shape, and is made of a material such as carbon fiber reinforced resin. The two up-down units **41***b* are coupled to opposite end portions of the fixing member **41***a* in the lengthwise direction, and have respective AC servo motors, ball screws, etc. The up-down units **41***b* move the fixing member **41***a* and the slit nozzle **1** integrally up and down in the vertical direction (Z direction) to adjust an interval between the ejection opening of the slit nozzle **1** and the substrate S, namely, the height of the ejection opening relative to an upper surface of substrate S.

[0025] The nozzle drive mechanism **42** includes two guide rails **43** along which the movement of the slit nozzle **1** is guided in the X direction, two linear motors **44** as drive sources, and two linear encoders **45** for detecting the position of the ejection opening of the slit nozzle **1**. The two guide rails **43** are arranged at opposite ends of the base **2** in the Y direction in such a manner as to interpose the stage **3** therebetween in the Y direction, and are extended in the X direction in such a manner as to cover the stage **3**. Respective lower end portions of the two up-down units **41***b* are guided along the corresponding two guide rails **43**, thereby moving the slit nozzle **1** in the X direction above the substrate S held on the stage **3**.

[0026] Each of the two linear motors **44** is an AC coreless linear motor having a stator **44***a* and a mover **44***b*. The stator **44***a* is arranged at each of side surfaces of the base **2** in the Y direction in such a manner as to extend in the X direction. The mover **44***b* is fixed externally to the up-down unit **41***b*. The linear motor **44** functions as a drive source of the nozzle drive mechanism **42** using magnetic force generated between the stator **44***a* and mover **44***b*.

[0027] Each of the two linear encoders **45** has a scaling part **45***a* and a detector **45***b*. The scaling part **45***a* is provided at the bottom of the stator **44***a* of the linear motor **44** fixed to the base **2**, and is extended in the X direction. The detector **45***b* is fixed still externally to the mover **44***b* of the linear motor **44** fixed to the up-down unit **41***b*, and is arranged face-to-face with the scaling part **45***a*. The linear encoder **45** detects the position of the ejection opening of the slit nozzle **1** in the X direction on the basis of the positions of the scaling part **45***a* and the detector **45***b* relative to each other. Specifically, in the present embodiment, while the up-down unit **41***b* adjusts an interval between the slit nozzle **1** and the substrate S in the Z direction, the nozzle drive mechanism **42** moves the slit nozzle **1** in the X direction relative to the substrate S. During this relative movement, the processing liquid is ejected from the slit nozzle **1** to supply the processing liquid to the upper surface of the substrate S (a coating process of applying the processing liquid).

[0028] FIG. **2** is a plan view of a principal part of the substrate holding mechanism viewed from above. FIG. **3** schematically shows the configuration of the substrate holding mechanism. The configuration and motion of the substrate holding mechanism **200** will be described by referring to these drawings.

[0029] In the substrate holding mechanism **200**, the stage **3** corresponds to an example of a "mounting table" of the present invention. The stage **3** used herein is a stone surface plate providing the mounting surface **31** with flatness of about several micrometers, for example. The mounting surface **31** has a central part functioning as a substrate mounting region **311** allowing the substrate S to be mounted therein. The substrate mounting region **311** has a central part where suction grooves **312** are formed in a grid pattern in response to an effective area of the substrate S, and a peripheral part with a plurality of suction pads **71** provided in such a manner as to surround the suction grooves **312**.

[0030] The effective area of the substrate S means a region for providing a plurality of elements in a central part of the upper surface of the substrate S. In the case of a semiconductor package, for example, a rectangular glass substrate corresponds to the substrate S, and a plurality of semiconductor chips, interconnect lines between the chips, and others stacked in a central part of an upper surface of the glass substrate correspond to the plurality of elements. When the substrate S is mounted in the substrate mounting region **311**, the effective area becomes located over the central part of the substrate mounting region **311**. As shown in FIG. **2**, in the central part of the substrate mounting region **311**, the suction grooves **312** are formed in a grid pattern in order to hold the effective area of the substrate S firmly under suction on the mounting surface **31**. Specifically, the grooves are extended in the X direction and the Y direction to a certain depth from the mounting surface **31**, and at some intersecting points where the grooves intersect each other, through holes **313** extending in the Z direction are formed that lead to a lower surface **32** of the stage **3** from the corresponding intersecting points.

[0031] As shown in FIG. **3**, each of the through holes **313** is connected to a negative pressure generator **5**. The negative pressure generator **5** includes a suction pipe **51**, a suction source **52**, and an on/off valve **53**. More specifically, the suction source **52** is connected to the through hole **313** via the suction pipe **51**. The suction source **52** to be used may be a vacuum pump or resources in a factory where the substrate processing apparatus **100** is installed, for example. The on/off valve **53** is interposed in the suction pipe **51**. In response to a closing command from the controller **10**, the on/off valve **53** is closed to stop supply of a negative pressure to the through hole **313**. In response to an opening command from the controller **10**, the on/off valve **53** is opened to supply a negative pressure to the through hole **313**. Specifically, when the on/off valve **53** is opened in response to the opening command from the controller **10** after mounting of the substrate S in the substrate mounting region **311**, a negative pressure is supplied to the through hole **313**, as will be described later. By doing so, air is exhausted from space sandwiched between a lower surface of the effective area of the substrate S and the mounting surface **31** via the suction groove **312** and the through hole **313**, thereby holding the substrate S under suction on the mounting surface **31**.

[0032] In this way, the effective area of the substrate S is held under suction by the negative pressure generator **5**. Meanwhile, a region external to the effective area, namely, a non-effective area is located over the peripheral part of the substrate mounting region **311**. Hence, on the occurrence of warpage in the non-effective area, air goes into exhaust target space (between the effective area and the stage **3**) from the warped portion to cause reduction in suction force. Then, in the present embodiment, in the peripheral part of the substrate mounting region **311**, a plurality of recesses is provided in the mounting surface **31** in such a manner as to surround the suction grooves **312** in a grid pattern, and the suction pad **71** is provided in each of the recesses. As shown in FIG. **3**, the suction pad **71** has a suction upper end portion provided with a suction opening **711** for sucking a lower surface of the substrate S, and a suction lower end portion sunk in the recess. Like the suction groove **312**, the suction lower end portion is connected to the negative pressure generator **5**. Thus, in response to a closing command from the controller **10**, the on/off valve **53** is closed to stop supply of a negative pressure to the suction pad **71**. At this time, the suction upper end portion of the suction pad **71** protrudes to be higher by about **1** mm than the mounting surface **31** and is capable of supporting a peripheral part of the substrate S from below kept in a non-sucked state. The height position of the suction opening **711** determined at this time (sign H**3** in FIG. **6**B described later) corresponds to an example of a “pad abutment position” of the present invention. Meanwhile, in response to an opening command from the controller **10**, the on/off valve **53** is opened to supply a negative pressure to the suction pad **71**. By doing so, suction of the substrate S is started.

[0033] The suction pad **71** has a so-called bellows shape and is expandable and contractible in the vertical direction Z. Thus, after the lower surface of the substrate S comes into abutting contact with the suction opening **711** of the suction pad **71**, namely, after formation of an abutment state, the suction upper end portion of the suction pad **71** retreats into the recess while keeping abutting contact with the substrate S in conjunction with downward movement of the substrate S caused by an up-down unit **6** described later to become sinkable in the recess at a moment when mounting of the substrate S on the mounting surface **31** is finished. As described, in the present embodiment, a suction unit **7** is composed of the plurality of suction pads **71**, and sucks and holds the peripheral part of the substrate S from below.
[0034] In the present embodiment, in response to opening and closing of the on/off valve **53**, a switch between sucking the substrate and stopping the suction using the suction groove **312** and a switch between sucking the substrate and stopping the suction using the suction pad **71** are made simultaneously. Meanwhile, in one configuration, these switches may be made independently of each other by providing an on/off valve dedicated to the suction groove and an on/off valve dedicated to the suction pad.
[0035] The up-down unit **6** has a plurality of lift pins **61** and a lift pin drive part **62**. The stage **3** is provided with a plurality of pin housing holes **315** extended parallel to the Z direction and opened at the mounting surface **31**, and the lift pins **61** are housed in the corresponding pin housing holes **315**. In the present embodiment, four pin housing holes **315** are provided and the substrate S is configured to be moved up and down by the four lift pins **61**. However, the number of the lift pins **61** is not limited to “4” but may be changed as appropriate in response to a planar size or weight of the substrate S, for example.
[0036] Each lift pin **61** is configured by attaching a head cap made of a resin material removably to a head of a lift pin body made of metal such as stainless steel, for example, and has a pin shape extended parallel to the Z direction as a whole. As the resin material forming the head cap, polyether ether ketone (PEEK) or ultra-high molecular weight polyethylene (UPE) is available, for example. A head portion, namely, the head cap of each lift pin **61** comes into contact with the lower surface of the substrate S as described next and is worn in response to an increased frequency of the contact. Thus, as the wear develops further, the head cap is changed regularly by an operator.
[0037] When the controller **10** for controlling the apparatus entirely gives an up-down command to the lift pin drive part **62**, the lift pin **61** is moved up and down. By doing so, the lift pin **61** moves forward and backward relative to the pin housing hole **315**. As shown in FIG. **3**, moving the lift pin **61** up until the head of the lift pin **61** reaches a height position H**1** allows the substrate S to be transferred to and from a robot not shown in the drawings. Namely, the height position H**1** corresponds to an example of a transfer position for the substrate S. When the substrate S having been transported by the robot reaches a position over the stage **3**, the lift pins **61** are driven by the lift pin drive part **62** to move up, thereby protruding from the pin housing holes **315** to become higher than the mounting surface **31**. Then, the respective upper ends of the lift pins **61** come into point contact with the lower surface of the substrate S and receive the substrate S. Next, the lift pins **61** are driven by the lift pin drive part **62** to move down to be housed into the pin housing holes **315**. By doing so, the substrate S is mounted in the substrate mounting region **311** from the upper ends of the lift pins **61**. In lifting the substrate S from the substrate mounting region **311**, the lift pins **61** are driven by the lift pin drive part **62** to move up, thereby protruding from the pin housing holes **315** to become higher than the mounting surface **31**.
[0038] In the present embodiment, a positioning position (sign H**2** in FIG. **6**B) is set between the transfer position (sign H**1** in FIGS. **3** and **6**A) and the pad abutment position (sign H**3** in FIG. **6**B) in the vertical direction Z. The positioning position is set in order to position the substrate S in a horizontal direction received from the robot and before being subjected to the coating process using a positioning unit **8** while avoiding sliding contact with the suction pad **71** (position adjusting process). Furthermore, in the present embodiment, a pressure unit **9** is provided for performing a

warpage correcting process of correcting a warpage of the substrate S simultaneously with or before or after implementation of the position adjusting process.

[0039] In the present embodiment, the positioning unit **8** and the pressure unit **9** are provided by employing configurations similar to the position adjusting mechanism and the pressure mechanism shown in Japanese Patent Application Laid-Open No. 2017-112197. Thus, in the following, detailed descriptions of the configurations of the positioning unit **8** and the pressure unit **9** will be omitted and the configurations of these units will be described briefly by referring to FIGS. **2** and **3**.

[0040] The positioning unit **8** includes eight position adjusters **81** in total arranged two by two along each side of the mounting surface **31**. Each of the position adjusters **81** includes a pin-shape alignment pin **82** extended parallel to the Z direction. Specifically, the two alignment pins **82** are arranged separately from each other in the horizontal direction along each side surface of the stage **3**. The alignment pin **82** is arranged higher than the mounting surface **31** in such a manner as to be horizontally movable between space over the stage **3** and separated space separated from the over space toward an external side of the stage. More specifically, as shown in FIG. **3**, a lower end of the alignment pin **82** is located in a position higher than the mounting surface **31** and lower than the pad abutment position (sign H**3** in FIG. **6**B). Meanwhile, an upper end of the alignment pin **82** is located in a position higher than the positioning position (sign H**2** in FIG. **6**B) and lower than the transfer position (sign H**1** in FIGS. **3** and **6**A). Thus, with the substrate S located in the positioning position, the alignment pin **82** faces an end surface Se of the substrate S in the horizontal direction.

[0041] An alignment pin drive part **83** is connected to the alignment pin **82** having the foregoing configuration. When the alignment pin drive part **83** is actuated in response to a positioning command from the controller **10**, the alignment pin **82** at a retreat position moves horizontally toward the substrate S in the positioning position to abut on the end surface Se of the substrate S. By doing so, the substrate S is located in a predetermined position in the horizontal direction (position adjusting process or may also be called an alignment process). When the controller **10** gives a retreat command to the alignment pin drive part **83** after implementation of the position adjusting process, the alignment pin **82** moves farther from the substrate S to return to the retreat position.

[0042] The pressure unit **9** includes four pressure parts **91** in total arranged one by one along each side of the mounting surface **31**. Each of the pressure parts **91** includes a pressure member **92** extended along a corresponding side of the mounting surface **31**. Each pressure member **92** is provided movably between a standby position, a temporary correction position, and a final correction position. The standby position means the position of the pressure member **92** during loading and unloading of the substrate S, during a period waiting for loading of the substrate S, and during implementation of the coating process. As shown in FIG. **3**, when the pressure member **92** is in the standby position separated externally from the substrate mounting region **311**, the pressure member **92** does not interfere with the substrate S being loaded and unloaded, thereby allowing the substrate S to be loaded and unloaded smoothly. During implementation of the coating process, the pressure member **92** is separated from the substrate S so does not interfere with the slit nozzle **1**, thereby allowing the coating process to be performed smoothly.

[0043] The temporary correction position means a position where pressure is applied from above to the peripheral part of the substrate S in the positioning position (see FIGS. **6**B and **6**C referred to later). Specifically, in the temporary correction position, a lower surface of the pressure member **92** covers the peripheral part of the substrate S from above and is located in the positioning position in the vertical direction Z (sign H**2** in FIG. **6**B). By doing so, even if the peripheral part of the substrate S in the positioning position has a shape warped upward, namely, even if the substrate S is warped into a recess shape, the pressure member **92** depresses the peripheral part of the substrate S from above in the temporary correction position to correct the warpage of the substrate S (temporary correcting process). As a result, even if the peripheral part of the substrate S is warped upward when the substrate S is loaded, the substrate S is subjected to the temporary correcting process in the positioning position to be supported by the plurality of lift pins **61** with the end surface Se of the substrate S facing a side surface of the alignment pin **82**. Thus, it is possible to perform the positioning process stably.

[0044] In performing the positioning process, both the alignment pin **82** and the pressure member **92** abut on the substrate S. In this regard, in a configuration of the present embodiment, an abutment region where the alignment pin **82** abuts on the end surface Se of the substrate S and a pressure region where the pressure member **92** applies pressure to the peripheral part of the substrate S differ from each other in a peripheral direction of the substrate S, as shown in FIG. **2**. As a result, it is possible to perform the temporary correcting process and the positioning process smoothly in the positioning position.

[0045] The final correction position means a position where the pressure member **92** applies pressure from above to the peripheral part of the substrate S mounted on the mounting surface **31** toward the mounting surface **31** (see FIG. **6**E referred to later). Specifically, at the final correction position, the substrate S is sandwiched between the lower surface of the pressure member **92** and the mounting surface **31** to correct the warpage of the substrate S (final correcting process).

[0046] Each pressure member **92** is connected to a pressure drive part **93**. When the pressure drive part **93** is actuated in response to a command from the controller **10**, the pressure member **92** moves from the standby position, passes through the temporary correction position and the final correction position, and then returns to the standby position. A substrate holding motion including a sequence of such pressing and moving motions is conducted on each substrate S by causing the controller **10** to control each part of the substrate holding mechanism **200** as described next according to a program stored in advance.

[0047] FIG. **4** is a flowchart showing an example of a substrate holding process performed by the substrate processing apparatus in FIG. **1**. FIG. **5** is a flowchart showing a procedure of temporary correction on the substrate taken by the substrate holding mechanism in FIG. **2**. FIGS. **6**A and **6**C to **6**E are motion explanatory views showing motions conducted according to the flowchart in FIG. **4**. FIG. **6**B is a motion explanatory view showing a motion conducted according to the flowchart in FIG. **5**.

[0048] In step S**101**, the pressure member **92** provided in response to each of the four sides of the mounting surface **31** moves to the standby position and is then put on standby. Specifically, as shown in FIG. **6**A, the pressure member **92** moves to a non-interference position higher than the transfer position H**1** and external to the substrate S being transported by a robot not shown in the drawings, and is then put on standby. As shown in FIG. **6**A, in subsequent step S**102**, each alignment pin **82** is located in the separated space. The upper end of the lift pin **61** is housed in the pin housing hole **315**. When the robot transports the substrate S to a position over the mounting surface **31**, each lift pin **61** moves up from the pin housing hole **315** and the upper end of each lift pin **61** comes into point contact with the substrate S in the transfer position H**1** (step S**103**), as represented as an arrow M**1** in FIG. **6**A. Then, the substrate S is received from the robot onto each lift pin **61** (step S**104**).

[0049] Next, as represented as an arrow M**2** in FIG. **6**B, the lift pin **61** moves down until the upper end of the lift pin **61** becomes located in the positioning position H**2**. By doing so, with the lower surface of the substrate S supported from below by the lift pin **61**, the substrate S is moved to the positioning position H**2** (step S**105**). Specifically, the central part of the substrate S is substantially aligned with the positioning position H**2** in the vertical direction Z. On the other hand, the peripheral part of the substrate S is not always aligned with the positioning position H**2**. The reason for this is that, if the peripheral part of the loaded substrate S is warped upward, for example, the end surface Se of the substrate S becomes higher than the positioning position H**2** in the vertical direction Z in some cases. Furthermore, a distance from the positioning position H**2** is proportionate to a degree of the warpage of the substrate S. If a degree of the warpage of the substrate S becomes greater, the end surface Se of the substrate S may become higher than the upper end of the alignment pin **82**. In this case, moving the alignment pin **82** horizontally toward the substrate causes the alignment pin **82** to abut directly on the lower surface of the substrate S, not on the end surface Se of the substrate S. This causes serious reduction in the accuracy of positioning the substrate in the horizontal direction.

[0050] Then, in the present embodiment, the temporary correcting process shown in FIG. **5** is performed on the substrate S (step S**106**). Specifically, as shown by arrows M**3** in FIG. **6**B, each of the four pressure members **92** moves horizontally to an advanced position to become located directly above a corresponding side of the substrate S (step S**201**). Next, as represented as an arrow M**4** in FIG. **6**B, each pressure member **92** moves down to the positioning position H**2** (step S**202**). At this time, if the peripheral part of the substrate S is warped upward, the pressure member **92** moving down to the positioning position H**2** applies pressure downward to the peripheral part of the substrate S with the warpage, thereby correcting the warpage of the substrate S to some extent. As a result, the peripheral part of the substrate S is located at a height substantially conforming to the positioning position H**2** and lower than the upper end of the alignment pin **82**. As a result, a side surface of the alignment pin **82** faces the end surface Se of the substrate S in the horizontal direction.

[0051] When the temporary correction on the substrate S is finished, each of the plurality of alignment pins **82** moves horizontally toward the substrate S in the positioning position H**2** as represented as a sign M**5** in FIG. **6**C to locate the substrate S in a predetermined position in the horizontal direction (step S**107**: positioning process). As represented as a sign M**6** in FIG. **6**C, the alignment pin **82** moves farther from the substrate S after the positioning process to return to the initial retreat position. In this way, in the present embodiment, the substrate S is subjected to the positioning process while the substrate S is separated upward from the suction pad **71**. As a result, the substrate S is located in the predetermined position in the horizontal direction relative to the mounting surface **31** while generation of dust from the suction pad **71** and wear of the suction pad **71** are prevented effectively.

[0052] Next, as represented as an arrow M**7** in FIG. **6**D, downward movement of the lift pin **61** is restarted (step S**108**). By doing so, the substrate S moves down toward the stage **3** while being supported by the lift pin **61**. In synchronization with this movement, the pressure member **92** also moves down toward the stage **3** (step S**109**). Specifically, if the substrate S moving down is in a state after being subjected to the temporary correcting process in step S**106**, the substrate S moves down in this temporarily corrected state.

[0053] During the downward movement of the substrate S, the peripheral part of the substrate S abuts on the suction opening **711** of the suction pad **71** (see FIG. **6**D). The lift pin **61** moves down further to house the upper end of the lift pin **61** into the pin housing hole **315**, and the suction upper end portion of the suction pad **71** retreats into the recess. By doing so, the substrate S is mounted from the upper end of each lift pin **61** on the mounting surface **31** (step S**110**). Furthermore, the pressure member **92** applies pressure to the peripheral part of the substrate S against the mounting surface **31**. By doing so, the shape of the substrate S is corrected so as to conform to the shape of the mounting surface **31**. In this way, in the present embodiment, the substrate S is mounted on the mounting surface **31** while the final correcting process is performed. Next, the suction source **52** sucks air through an air hole, thereby sucking the substrate S on the mounting surface **31** (step S**111**). As a result, the substrate S is fixed to the mounting surface **31**. Then, the pressure member **92** returns to the initial standby position. By doing so, the substrate holding process is finished. The coating process using the slit nozzle **1** is performed thereafter.

[0054] As described above, in the present embodiment, while the substrate S is supported from below by the plurality of lift pins **61** in the positioning position H**2** separated upward from the suction pad **71**, the alignment pin **82** abuts on the end surface Se of the substrate S. By doing so, the substrate S is aligned in a predetermined position in the horizontal direction relative to the

mounting surface **31**. During implementation of this positioning process (alignment process), the substrate S is separated from the suction pad **71** and is moved in a non-abutment state in the horizontal direction. After the positioning, the substrate S is mounted on the mounting surface **31** and is sucked under suction by the suction pad **71**. Thus, while generation of dust from the suction pad **71** and wear of the suction pad **71** are prevented, it is possible to hold the substrate S under suction on the mounting table using the suction pad **71** with the substrate S located in the predetermined position relative to the mounting surface **31**.
[0055] The temporary correcting process using the pressure unit **9** is performed in the positioning position H**2** before implementation of the positioning process using the alignment pin **82**. Thus, even if the loaded substrate S is warped upward at its peripheral part, the peripheral part of the substrate S is corrected to a height substantially equal to the positioning position H**2** in the vertical direction Z, thereby allowing the alignment pin **82** to abut on the end surface Se of the substrate S reliably. Furthermore, in the present embodiment, the positioning process (alignment process) using the alignment pin **82** is performed while the pressure member **92** keeps making the temporary correction by applying pressure from above to the peripheral part of the substrate S. This allows the positioning process using the alignment pin **82** to be performed with high accuracy.
[0056] In the present embodiment, after positioning of the substrate S, the alignment pin **82** moves farther from the end surface Se of the substrate S and the lift pin **61** moves down to mount the substrate S on the mounting surface **31**. At the same time, the peripheral part of the substrate S mounted on the mounting surface **31** is sandwiched between the mounting surface **31** and the pressure member **92** to correct the peripheral part of the substrate S (final correcting process). As a target of application of the processing liquid is the substrate S after being subjected to the final correcting process, it is possible to apply the processing liquid favorably to the surface Sa of the substrate S.
[0057] As described above, in the foregoing embodiment, the lift pin **61** corresponds to an example of a “support pin” of the present invention, and the alignment pin **82** corresponds to an example of a “positioning member” of the present invention.
[0058] The present invention is not limited to the foregoing embodiment but can be changed in various ways other than those described above without departing from the purport of the invention. As an example, in the above-described embodiment, a speed at which the substrate S moves down is determined freely. Meanwhile, the downward movement speed may be changed with reference to the pad abutment position H**3**. More specifically, with a speed of moving down from the positioning position H**2** to the pad abutment position H**3** and a speed of moving down from the pad abutment position H**3** to the mounting surface defined as a “first downward movement speed” and a “second downward movement speed” respectively, the second downward movement speed may be set lower than the first downward movement speed. This is intended to cause expansion and contraction of the suction pad **71** to follow the downward movement of the substrate using the lift pin **61** without delay.
[0059] In the above-described embodiment, holding of the substrate S under suction is started after the substrate S is mounted on the mounting surface **31**. However, timing of starting the suction is not limited to this. For example, start of the holding under suction may be timed to coincide with arrival of the moving-down substrate S at the pad abutment position H**3**.
[0060] In the above-described embodiment, the alignment pin **82** is used as the “positioning member” of the present invention. However, the shape of the “positioning member” is not limited to this but a block member having a columnar shape may be used as an example of the “positioning member,” for example.
[0061] Although the invention has been described by way of the specific embodiments above, this description is not intended to be interpreted in a limited sense. By referring to the description of the invention, various modifications of the disclosed embodiments will become apparent to a person skilled in this art similarly to other embodiments of the invention. Hence, appended claims are

thought to include these modifications and embodiments without departing from the true scope of the invention.
[0062] The present invention can be applied to a substrate holding device and method of holding substrates on mounting tables and a substrate processing apparatus technique of applying processing liquids to the substrates held on the mounting tables by supplying the processing liquids from slit nozzles.

Claims

1. A substrate holding device comprising: a mounting table having a mounting surface on which a substrate is to be mounted; an up-down unit configured to mount the substrate on the mounting surface by moving down a plurality of support pins supporting the substrate from below; a suction unit configured to suck and hold a peripheral part of the substrate from below using a suction pad; a positioning unit configured to position the substrate by abutting on an end surface of the substrate supported by the plurality of support pins at a positioning position separated upward from the suction pad; and a controller configured to control the up-down unit, the suction unit, and the positioning unit so as to cause the up-down unit to mount the substrate on the mounting surface and to cause the suction unit to hold the substrate under suction while the substrate is positioned by the positioning unit.
2. The substrate holding device according to claim 1, comprising: a pressure unit from which pressure is applicable from above to the peripheral part of the substrate supported by the plurality of support pins in the positioning position.
3. The substrate holding device according to claim 2, wherein an abutment region where the positioning unit abuts on the end surface of the substrate and a pressure region where the pressure unit applies pressure to the peripheral part of the substrate differ from each other in a peripheral direction of the substrate.
4. The substrate holding device according to claim 3, wherein the controller is configured to control the positioning unit and the pressure unit so as to cause the positioning unit to abut on the end surface of the substrate to position the substrate while causing the pressure unit to keep applying pressure to the peripheral part of the substrate.
5. The substrate holding device according to claim 4, wherein the controller is configured to control the positioning unit and the up-down unit so as to cause the positioning unit to move farther from the end surface of the substrate after positioning of the substrate and to cause the up-down unit to move down the plurality of support pins to mount the substrate on the mounting surface.
6. The substrate holding device according to claim 5, wherein the controller is configured to control the pressure unit so as to cause the pressure unit to move down together with downward movement of the plurality of support pins to sandwich the peripheral part of the substrate mounted on the mounting surface between the pressure unit and the mounting surface.
7. The substrate holding device according to claim 1, wherein the suction pad has a suction upper end portion provided with a suction opening for sucking a lower surface of the substrate, and a suction lower end portion sunk in a recess provided in the mounting surface, while the suction upper end portion is in a non-abutment state of not abutting on the lower surface of the substrate, the suction upper end portion protrudes to a pad abutment position higher than the mounting surface and lower than the positioning position, and while the suction upper end portion is in an abutment state of abutting on the lower surface of the substrate, the suction upper end portion retreats into the recess in conjunction with downward movement of the substrate to become sinkable in the recess at a moment when mounting of the substrate on the mounting surface is finished.
8. The substrate holding device according to claim 7, wherein the controller is configured to control the up-down unit so as to move down the substrate from the positioning position to the pad

abutment position at a first downward movement speed and to move down the substrate from the pad abutment position to the mounting surface at a second downward movement speed lower than the first downward movement speed.

9. A substrate processing apparatus comprising: the substrate holding device according to claim 1; and a slit nozzle configured to apply a processing liquid to a surface of the substrate by moving relative to the substrate in a horizontal direction while the substrate is mounted on the mounting surface and is held under suction on the mounting table by the suction pad.

10. A substrate holding method comprising: (a) sucking and holding a substrate on a mounting surface of a mounting table using a suction pad of a suction unit; (b) after the operation (a), positioning the substrate above the mounting surface and the suction pad by causing a positioning member to abut on an end surface of the substrate while supporting the substrate from below using a plurality of support pins; and (c) after the operation (b), mounting the substrate on the mounting surface by moving down the plurality of support pins.