(19) **United States**

(12) **Patent Application Publication**

YOON et al.

(10) **Pub. No.: US 2024/0234171 A1**

(43) **Pub. Date: Jul. 11, 2024**

(54) **SUBSTRATE PROCESSING APPARATUS AND SUBSTRATE PROCESSING METHOD**

(71) Applicant: **SEMES CO., LTD.**, Cheonan-si (KR)

(72) Inventors: **Do Hyeon YOON**, Cheonan-si (KR); **Eun Seok KIM**, Cheonan-si (KR); **Mi So PARK**, Cheonan-si (KR)

(73) Assignee: **SEMES CO., LTD.**, Cheonan-si (KR)

(21) Appl. No.: **18/406,880**

(22) Filed: **Jan. 8, 2024**

(30) **Foreign Application Priority Data**

Jan. 11, 2023 (KR) 10-2023-0003938

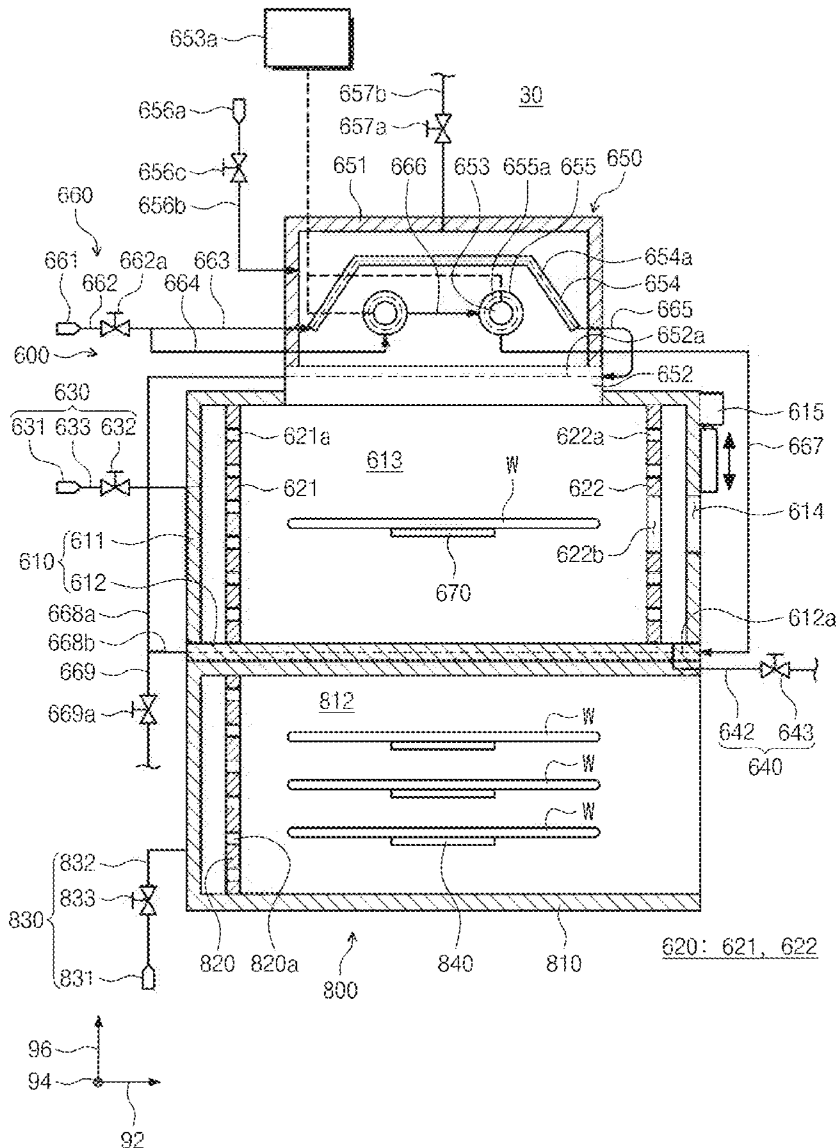
Publication Classification

(51) **Int. Cl.**
H01L 21/67 (2006.01)

(52) **U.S. Cl.**
CPC *H01L 21/67028* (2013.01)

(57) **ABSTRACT**

Provided is an apparatus for processing a substrate, the apparatus including: a liquid treatment chamber; a drying chamber; and a light treatment chamber, in which the light treatment chamber includes: a treatment housing having a treatment space in which the substrate is processed; a support member for supporting the substrate in the treatment space; a light source for irradiating the substrate supported on the support member with light in the form of pulses; and a light filter for selecting a set range of wavelengths of the light generated by the light source and allowing the selected wavelengths to pass through.



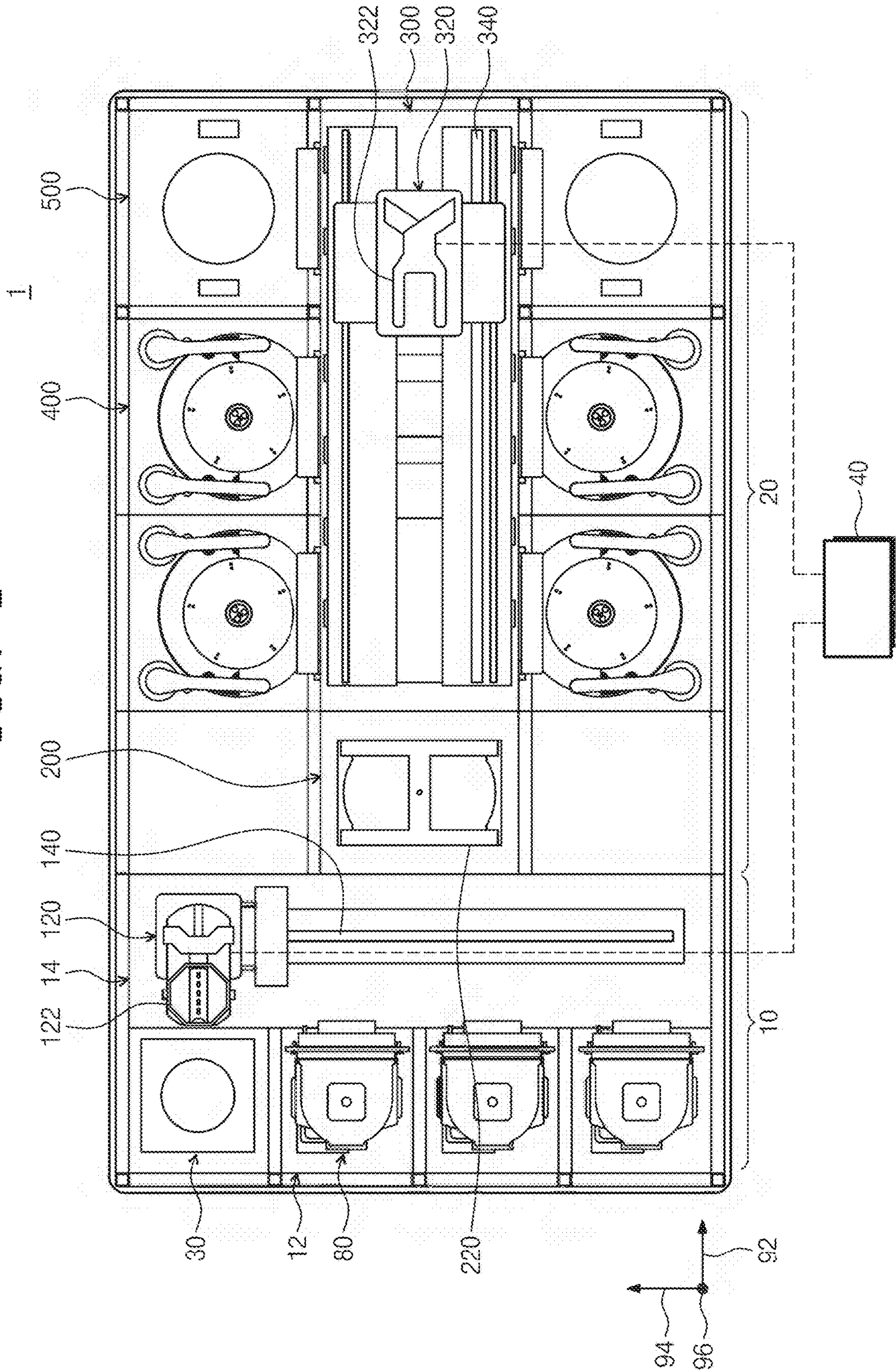


FIG. 1
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FIG. 2

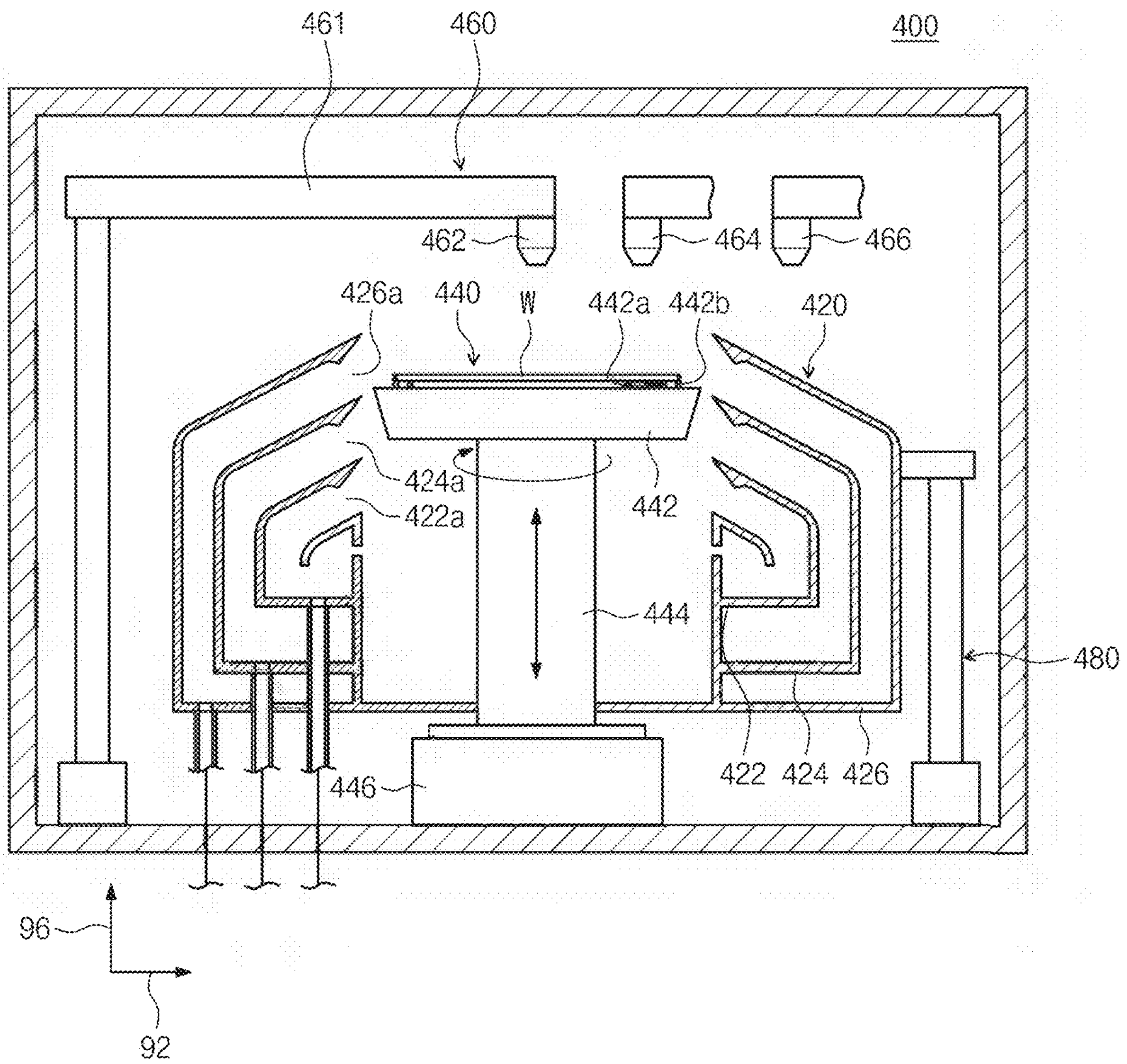


FIG. 3

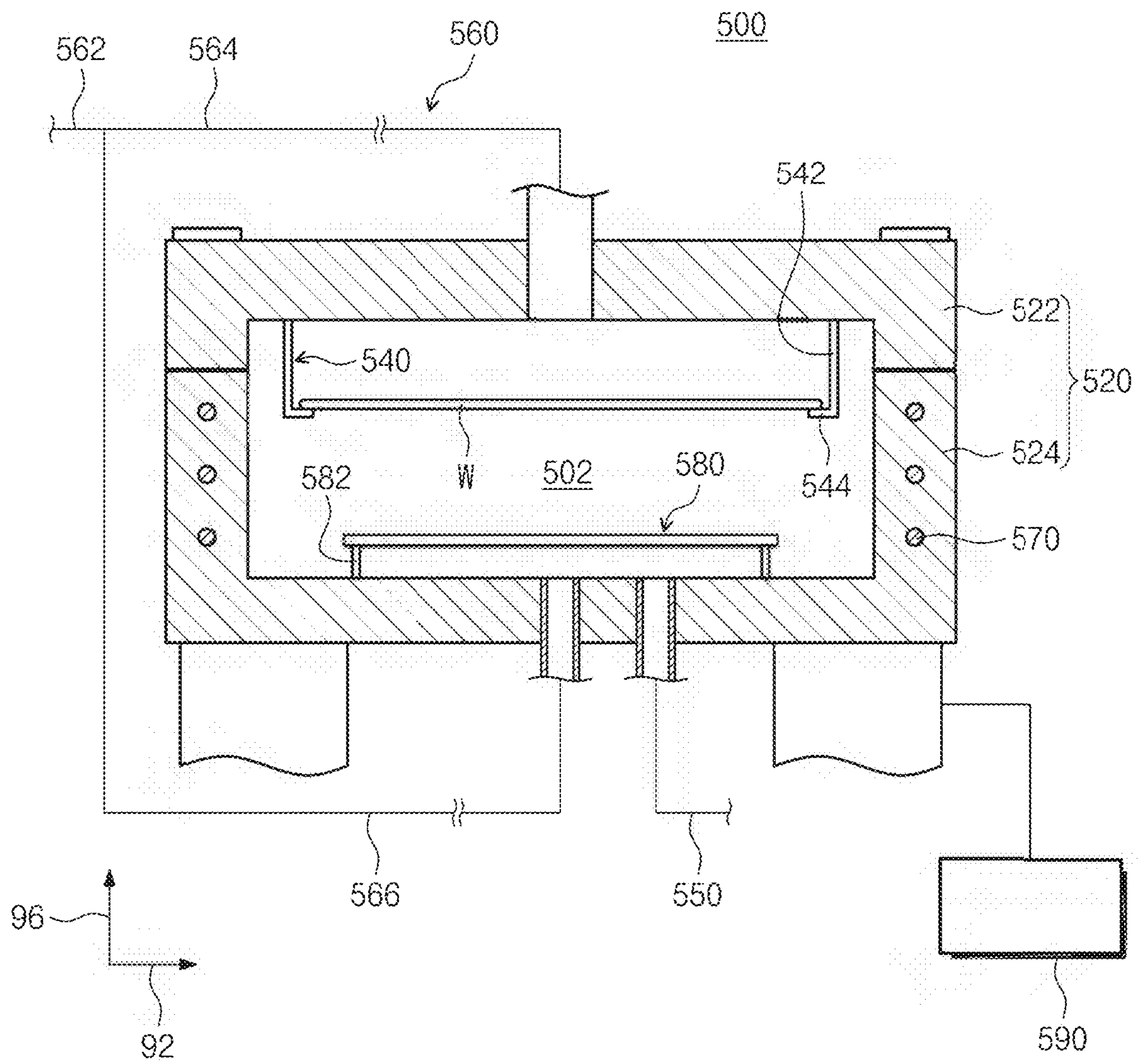


FIG. 4

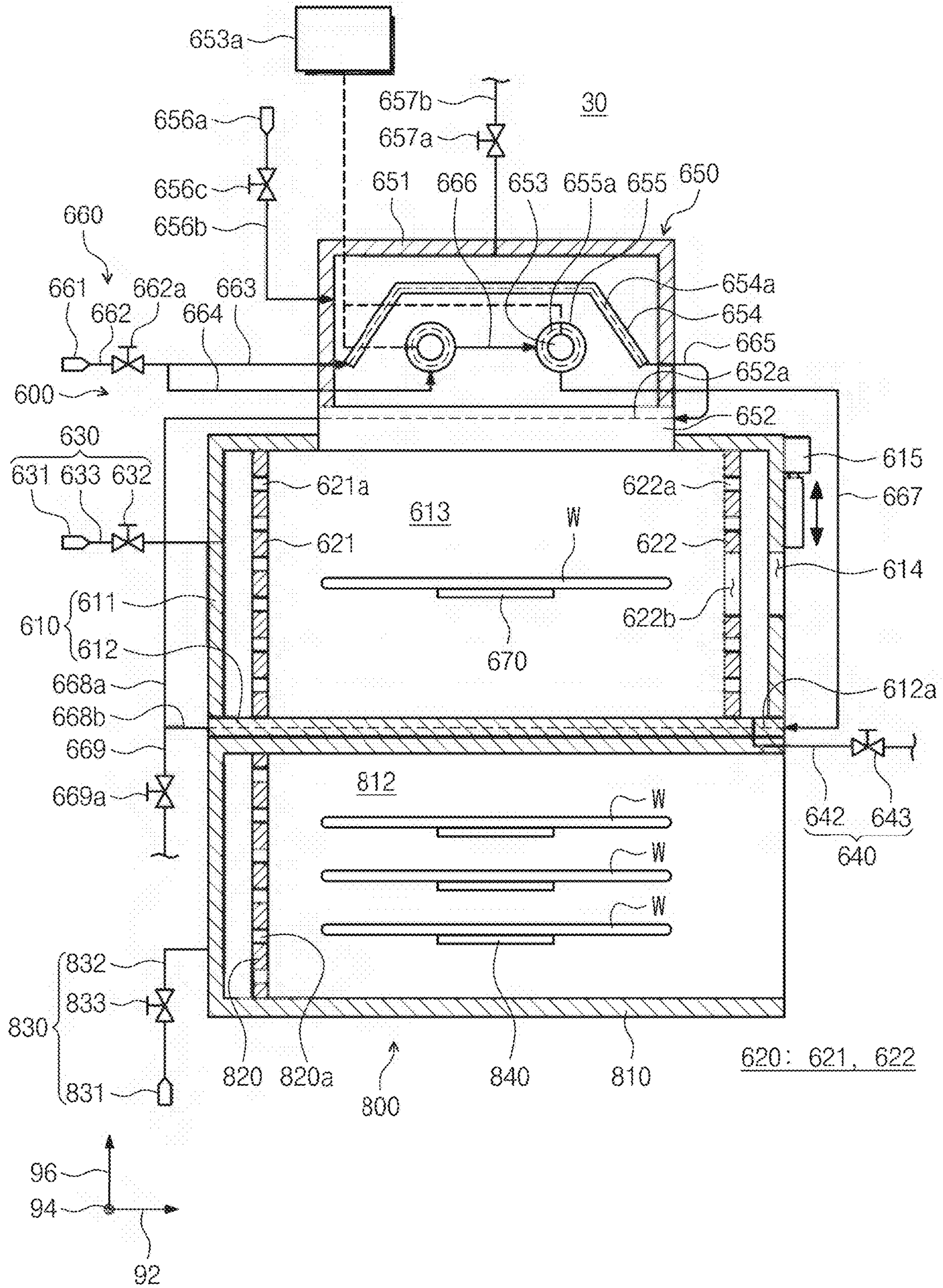


FIG. 5

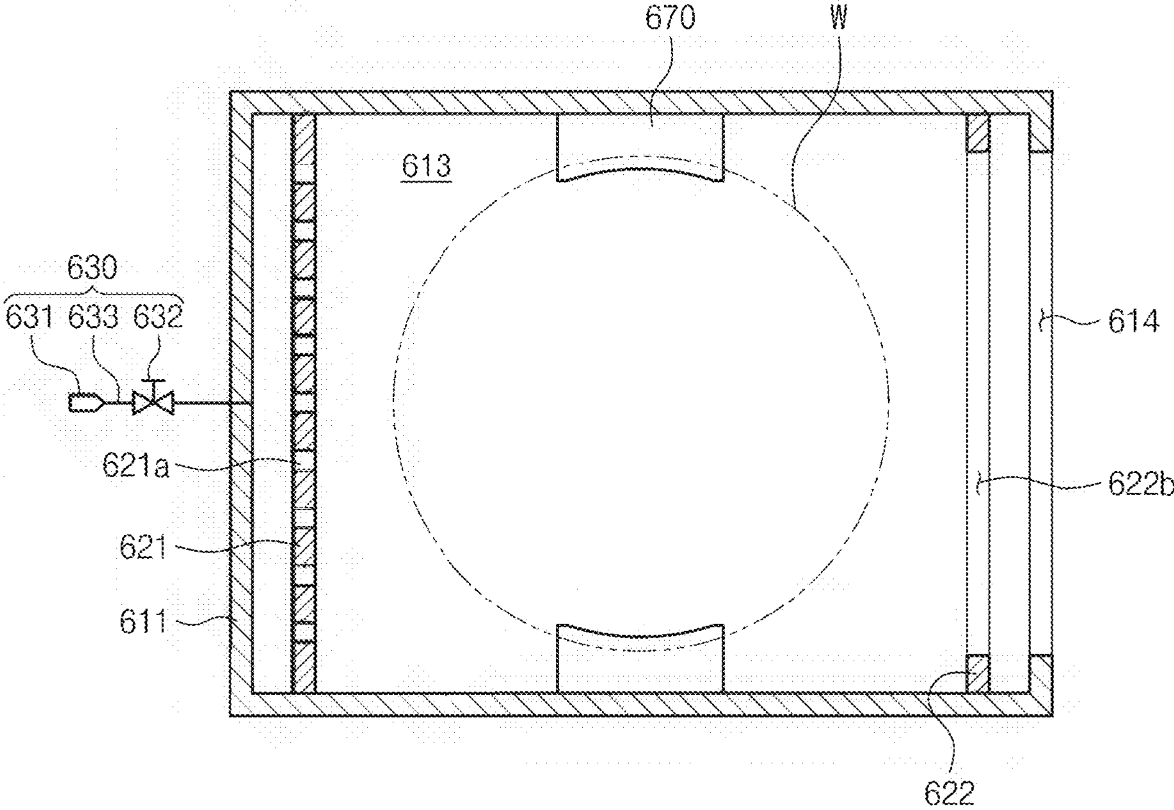


FIG. 6

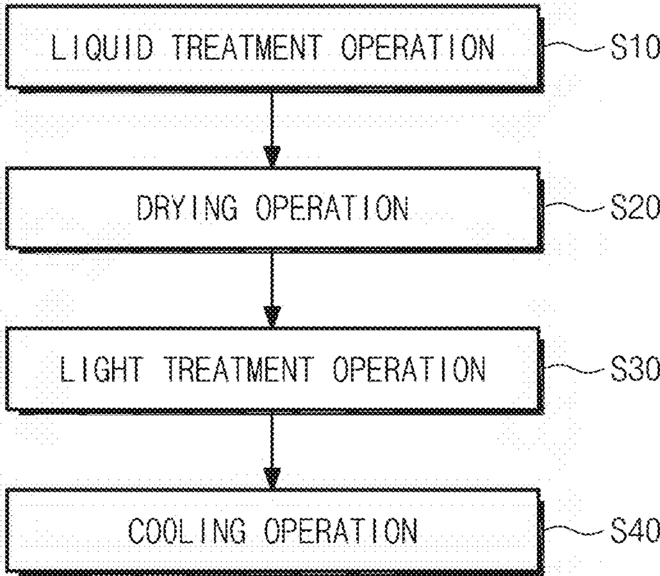


FIG. 7

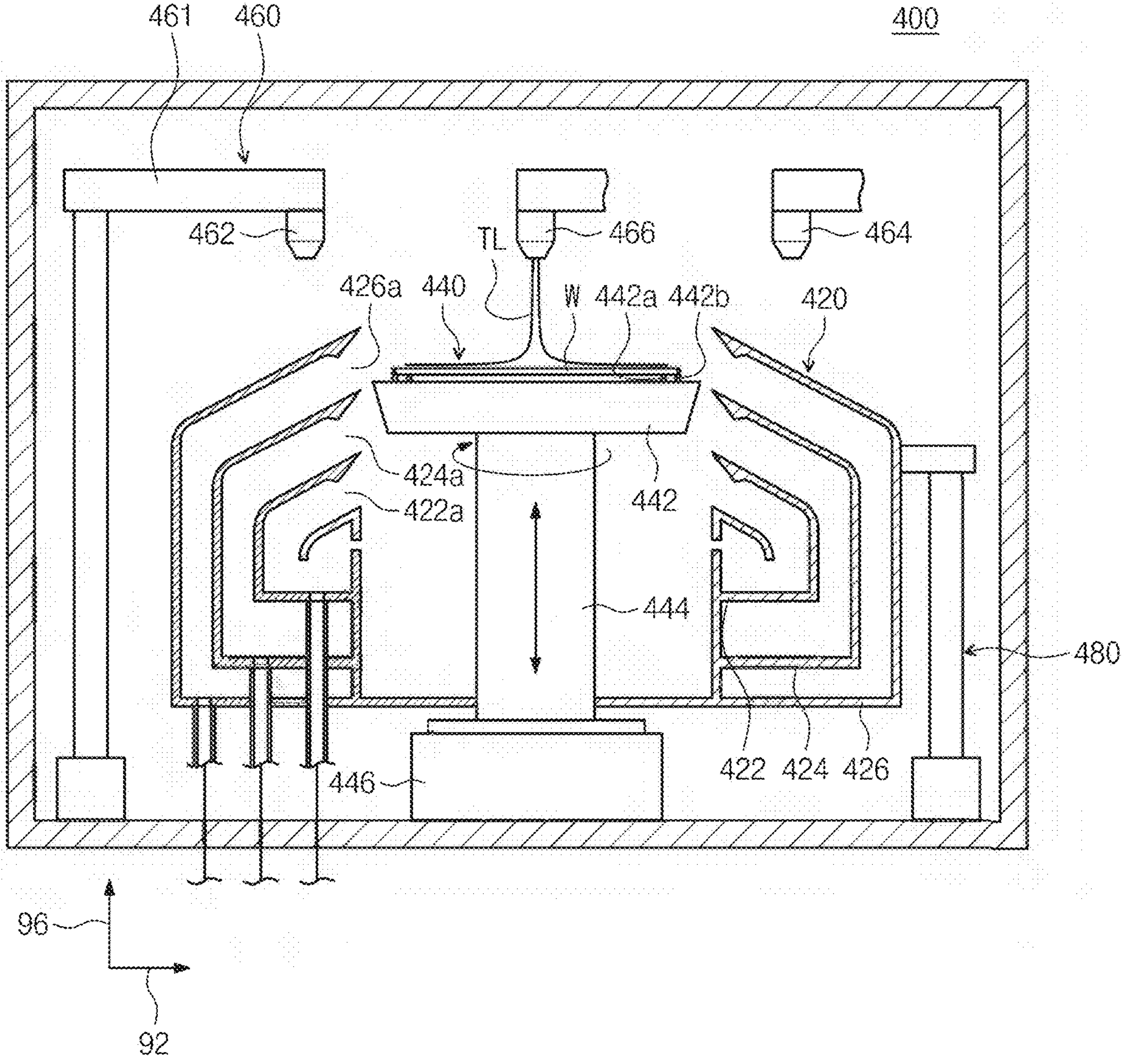


FIG. 8

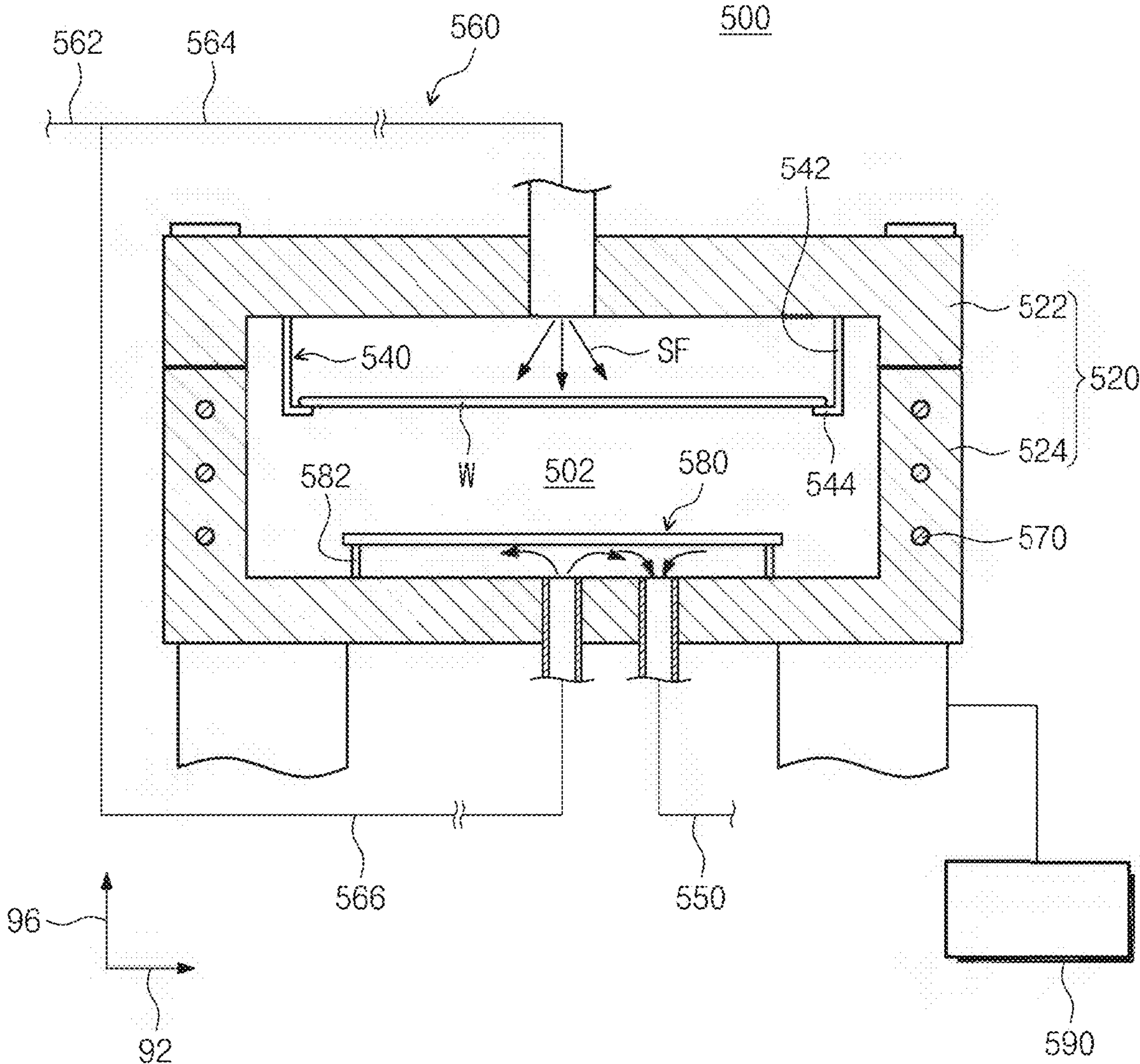


FIG. 9

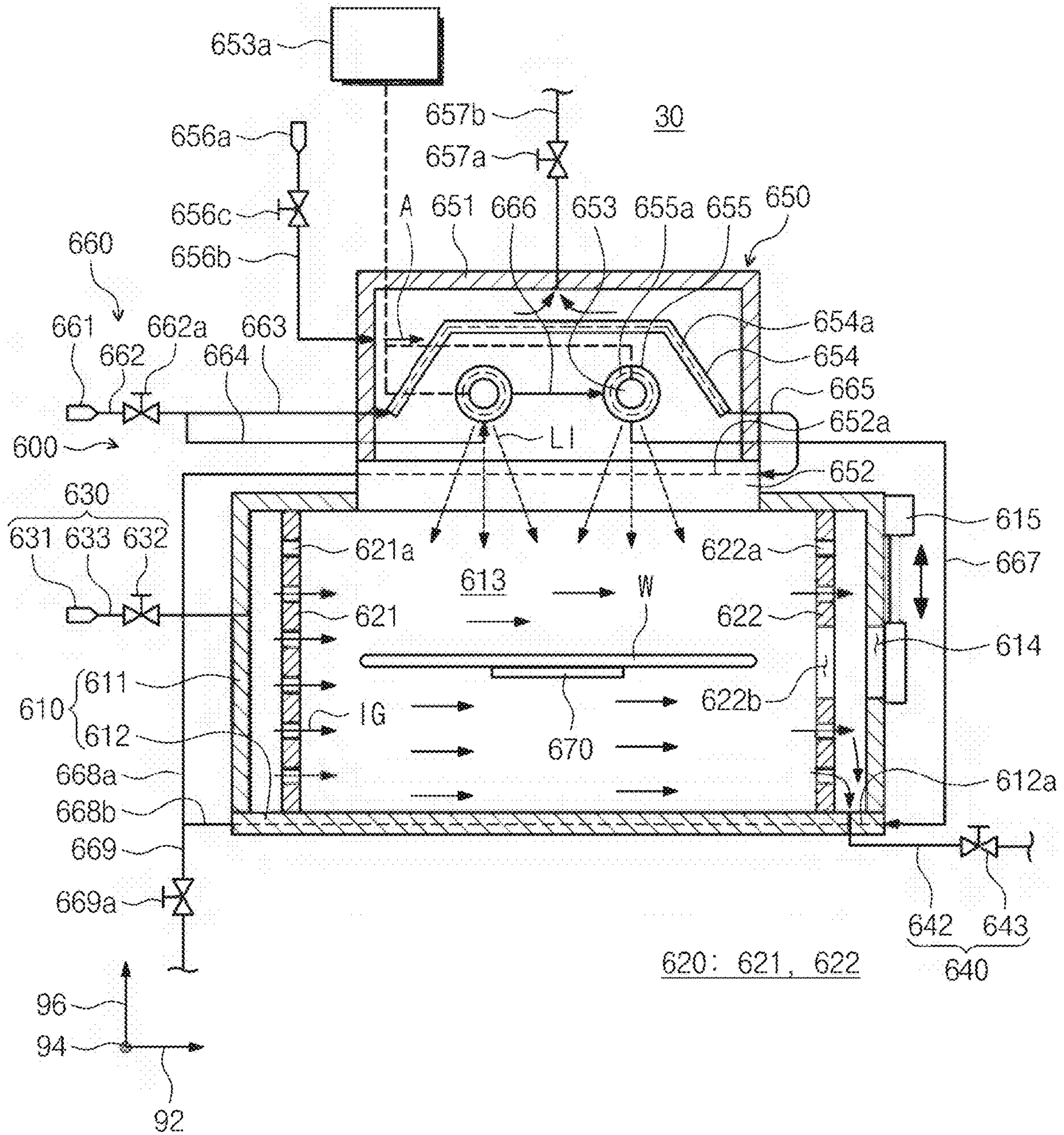


FIG. 10

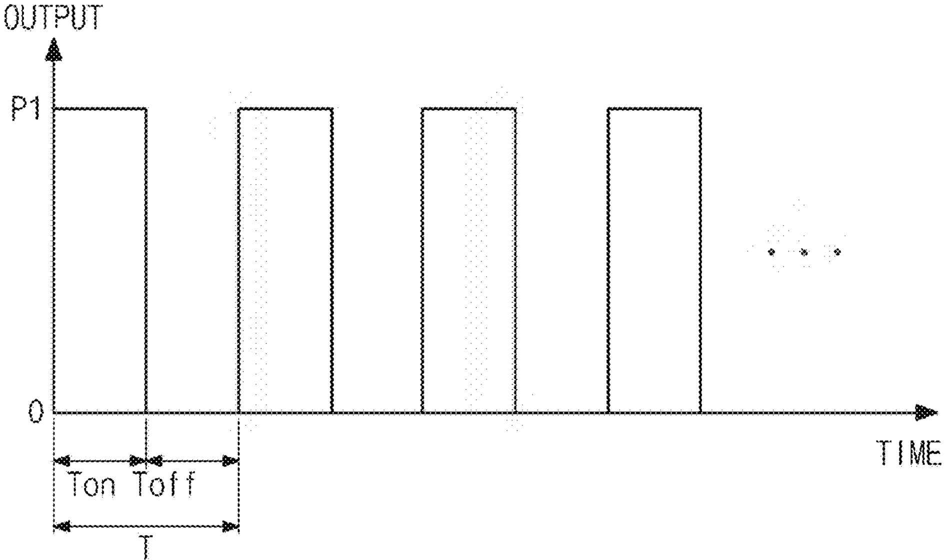


FIG. 11

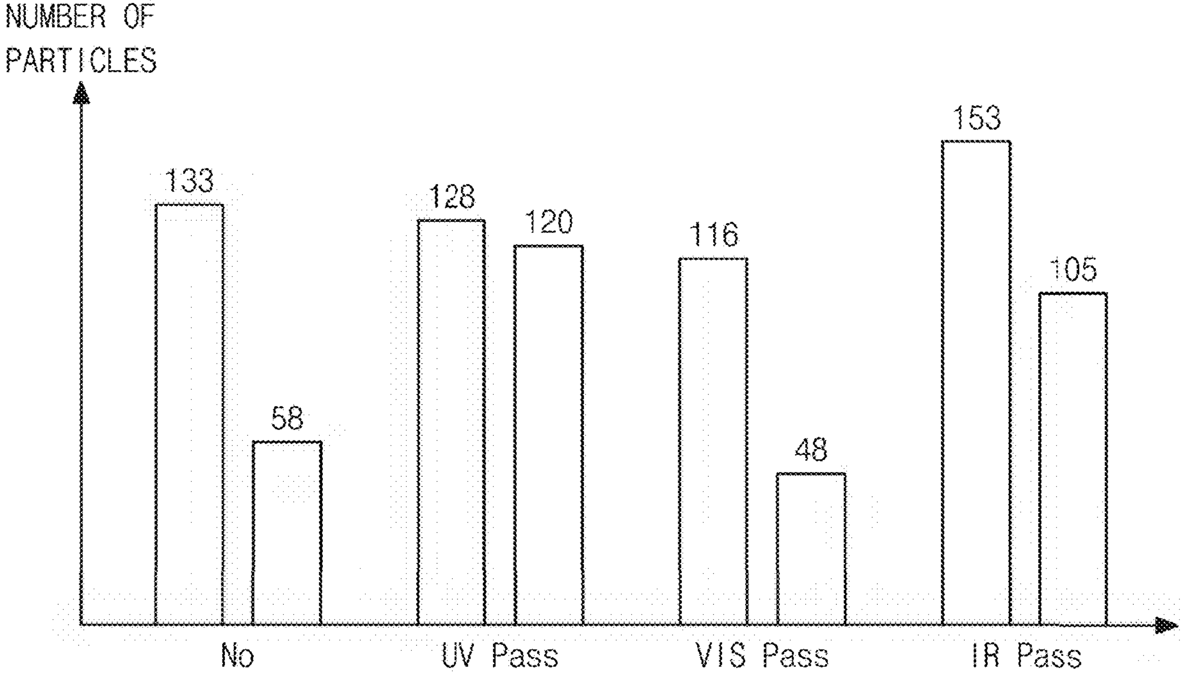


FIG. 12

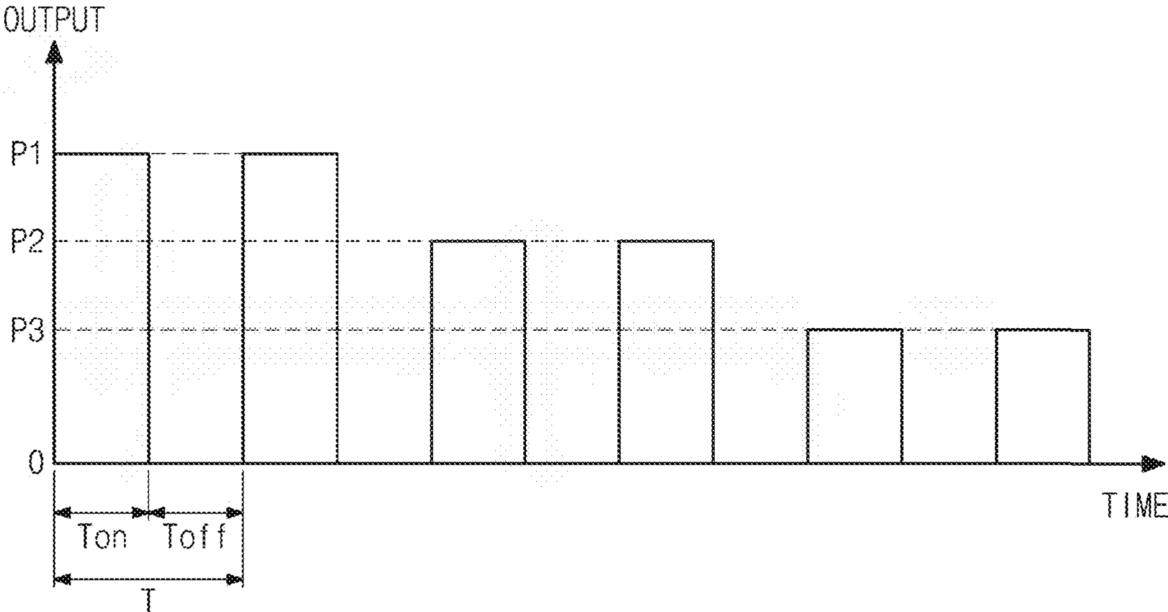
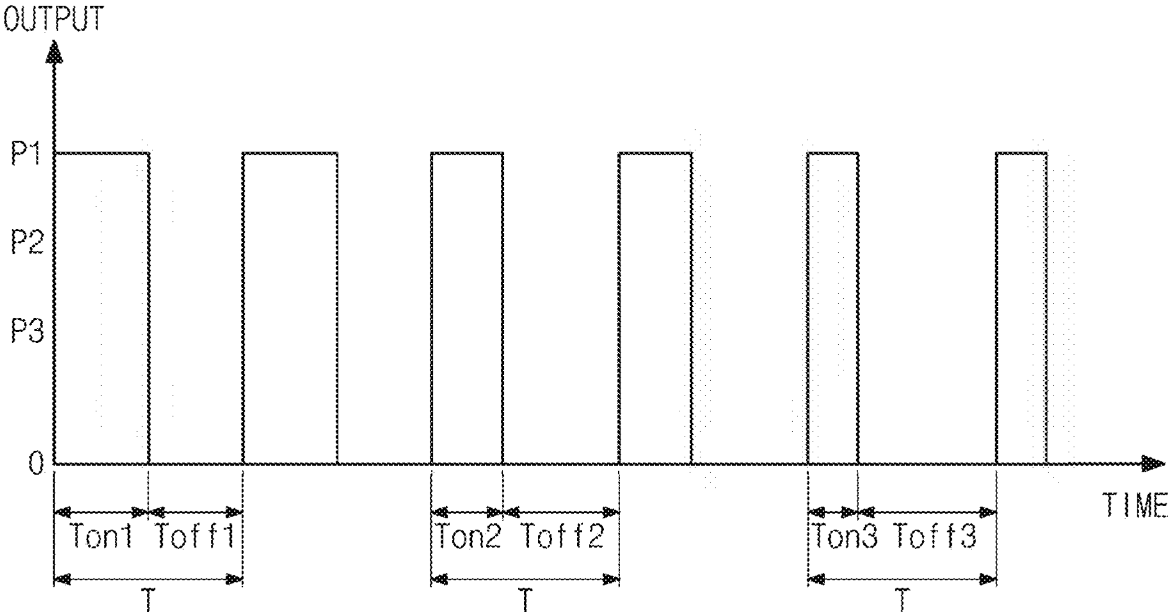


FIG. 13



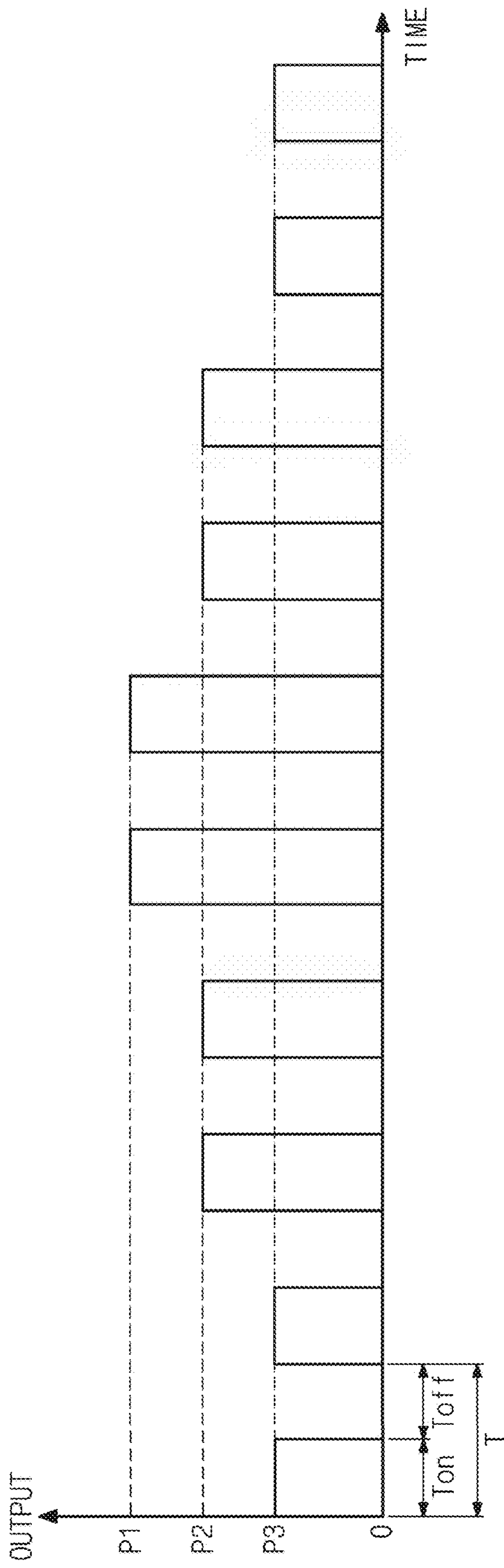


FIG. 14

FIG. 15

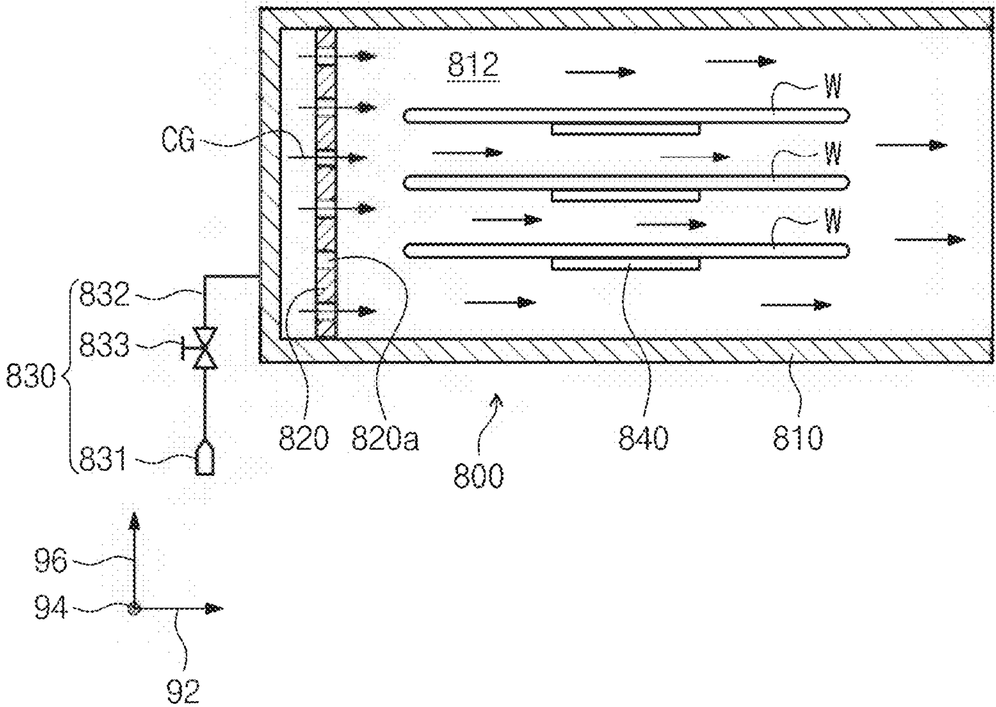


FIG. 16

FIG. 17

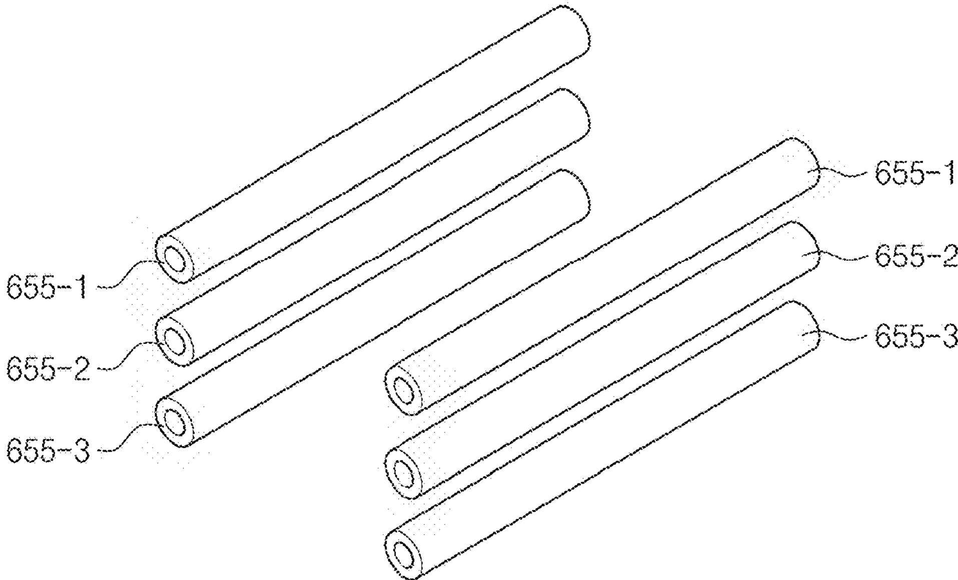
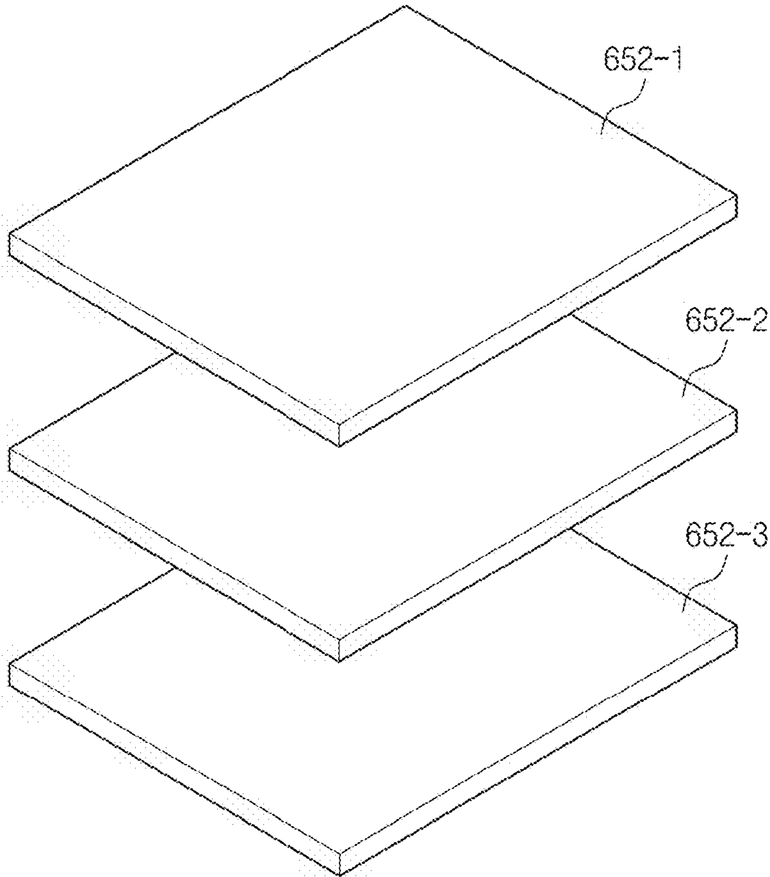


FIG. 18



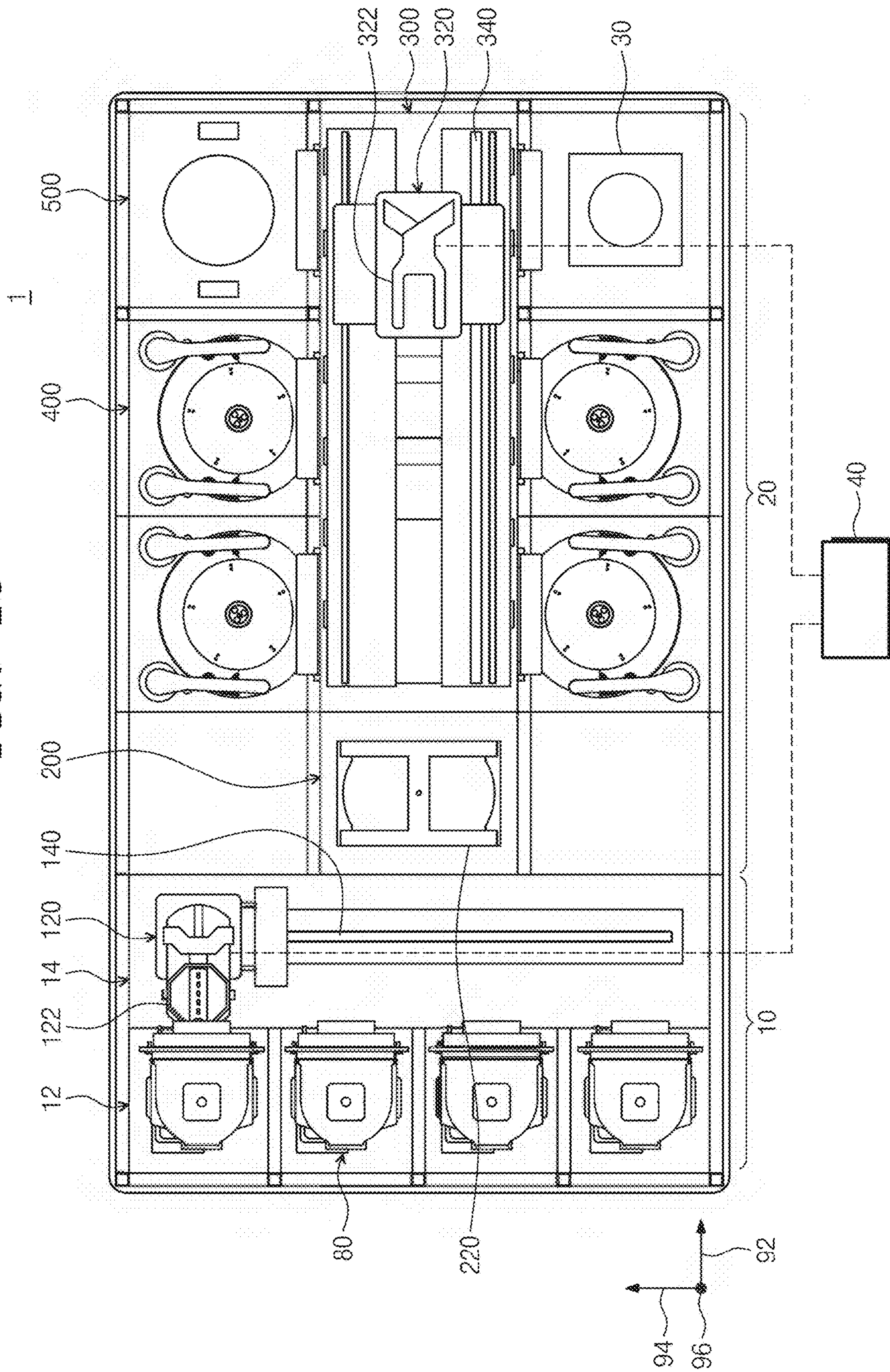


FIG. 19
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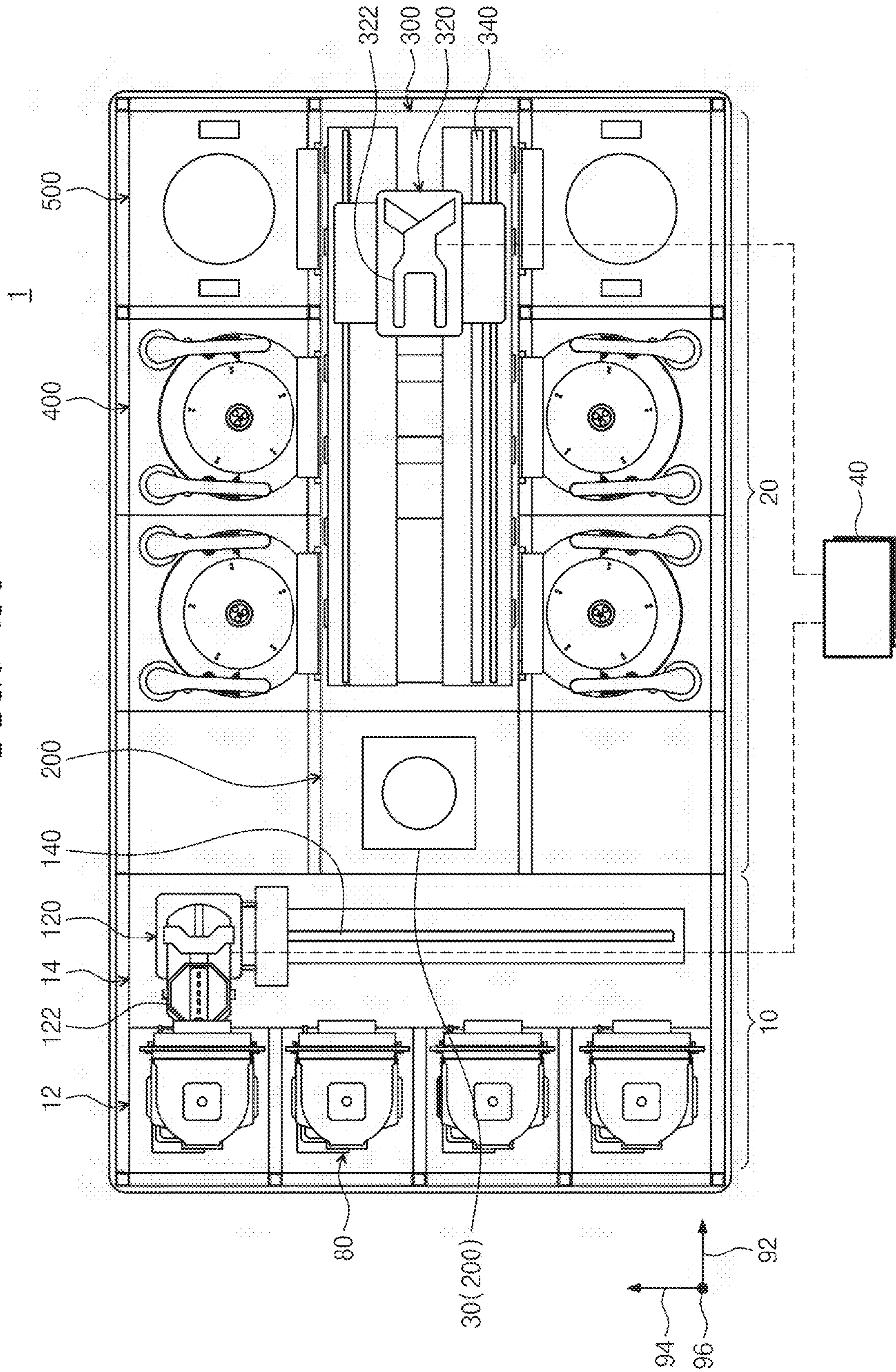
FIG. 20
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SUBSTRATE PROCESSING APPARATUS AND SUBSTRATE PROCESSING METHOD

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to and the benefit of Korean Patent Application No. 10-2023-0003938 filed in the Korean Intellectual Property Office on Jan. 11, 2023 the entire contents of which are incorporated herein by reference.

TECHNICAL FIELD

[0002] The present invention relates to a substrate processing apparatus and a substrate processing method.

BACKGROUND ART

[0003] Semiconductor processing includes cleaning processes to remove thin films, foreign substances, particles, and the like. from substrates, such as wafers. These processes are accomplished by placing a substrate on a spin head with a patterned side facing up or down, supplying a treatment liquid to the substrate while the spin head is rotated, and subsequently drying the wafer.

[0004] More recently, supercritical fluids have been used in substrate cleaning processes. According to the example, a substrate treatment device is provided with a liquid treatment chamber for performing liquid treatment on a substrate by supplying a treatment liquid to the substrate, and a drying chamber for removing the treatment liquid from the substrate using a supercritical fluid after the liquid treatment, and the substrate that has been treated in the liquid treatment chamber is loaded into to the drying chamber by a transfer robot.

[0005] The liquid treatment chamber(s) supplies a rinse liquid, such as pure water, to the substrate and then supplies an organic solvent, such as isopropyl alcohol, to substitute the supplied rinse liquid with the substrate. The substrate is then loaded into the drying chamber while having a liquid film formed by the organic solvent. The drying chamber removes the residual rinse liquid and/or organic solvent on the substrate by using a supercritical carbon dioxide fluid.

[0006] Organic matter may remain on the substrate on which the liquid treatment in the liquid treatment chamber and the drying treatment in the drying chamber had been performed. Residual organic matter on the substrate may cause failures in a semiconductor device manufactured by the substrate.

SUMMARY OF THE INVENTION

[0007] The present invention has been made in an effort to provide a substrate processing apparatus and a substrate processing method that may efficiently remove organic matter residual on a substrate by irradiating the substrate with light.

[0008] The present invention has also been made in an effort to provide a substrate processing apparatus and a substrate processing method that may minimize the occurrence of a warpage phenomenon or a broken phenomenon of a substrate when treating a substrate by irradiating the substrate with light, while maintaining high efficiency of removal of organic matters residual on the substrate.

[0009] The present invention has also been made in an effort to provide a substrate processing apparatus and a substrate processing method that may select a wavelength of light transmitted to a substrate according to a type of organic matter residual on the substrate.

[0010] The object of the present invention is not limited thereto, and other objects not mentioned will be clearly understood by those of ordinary skill in the art from the following description.

[0011] An exemplary embodiment of the present invention provides an apparatus for processing a substrate, the apparatus including: a liquid treatment chamber for liquid-treating a substrate by supplying a treatment liquid to the substrate; a drying chamber for drying-treating the substrate treated in the liquid treatment chamber; and a light treatment chamber for irradiating the substrate treated in the drying chamber with light to remove an organic matter residual on the substrate, in which the light treatment chamber includes: a treatment housing having a treatment space in which the substrate is processed; a support member for supporting the substrate in the treatment space; a light source for irradiating the substrate supported on the support member with light in the form of pulses; and a light filter for selecting a set range of wavelengths of the light generated by the light source and allowing the selected wavelengths to pass through.

[0012] According to the exemplary embodiment, the light filter may be configured to filter wavelengths, other than wavelengths of a visible light range, in the wavelengths of the light generated by the light source.

[0013] According to the exemplary embodiment, the light filter may have a tube shape surrounding the light source.

[0014] According to the exemplary embodiment, the light filter may be formed from a material including quartz, and a film that filters wavelengths other than the wavelengths of the visible light range is attached to a surface of the light filter, or a coating layer is formed on a surface of the light filter.

[0015] According to the exemplary embodiment, the light treatment chamber may include: a light source housing that defines a space in which the light source is placed, and the light filter is disposed between the light source housing and the treatment housing, and the light filter may have a plate shape to compartmentalize the treatment space of the treatment housing and the space of the light source housing from each other, and a film that filters the wavelengths other than the wavelengths of the visible light range may be attached to a surface of the light filter or a coating layer may be formed on a surface of the light filter.

[0016] According to the exemplary embodiment, the light filter may be configured to filter wavelengths in the range of 350 to 700 nm in the wavelengths of the light generated by the light source.

[0017] According to the exemplary embodiment, the light source may be a xenon flash lamp, and generate light having wavelengths in the range of 300 to 1000 nm.

[0018] According to the exemplary embodiment, the apparatus may further include a light source controller for controlling an operation of the light source, in which the light source controller may be configured to control at least one of an output of the light generated by the light source, a duty ratio in a unit pulse of light, and a period of the unit pulse of light.

[0019] According to the exemplary embodiment, the light source controller may control the light source such that an output of the unit pulse of the light generated by the light

source in an on state or a high state is constant during light treatment of the substrate supported on the support member.

[0020] According to the exemplary embodiment, the light source controller may control the light source such that an output of the unit pulse of the light generated by the light source in an on state or a high state becomes gradually smaller during light treatment of the substrate supported on the support member.

[0021] According to the exemplary embodiment, the light source controller may control the light source such that the duty ratio of the unit pulse of the light generated by the light source varies during light treatment of the substrate supported on the support member.

[0022] According to the exemplary embodiment, the light source controller may control the light source such that the duty ratio of the unit pulse of the light generated by the light source becomes gradually smaller during light treatment of the substrate supported on the support member.

[0023] Another exemplary embodiment of the present invention provides a method of processing a substrate, the method including: a liquid treatment operation of liquid-treating a substrate by supplying a treatment liquid to the substrate; a drying operation of drying-treating the substrate by supplying a supercritical fluid to the liquid-treated substrate; and a light treatment operation of irradiating the drying-treated substrate with light to remove an organic matter residual on the substrate, in which in the light treatment operation, the light is generated in the form of pulses, but a set range of wavelengths of the light is selected by a light filter to be emitted to the substrate.

[0024] According to the exemplary embodiment, the light treatment operation may include selecting wavelengths in the visible light range in the wavelengths of the light and emitting the selected wavelengths to the substrate.

[0025] According to the exemplary embodiment, the light treatment operation may include selecting wavelengths in the range of 350 to 700 nm in the wavelengths of the light and emitting the selected wavelengths to the substrate.

[0026] According to the exemplary embodiment, the light may have wavelengths in the range of 300 to 1000 nm and is generated by a xenon flash lamp.

[0027] According to the exemplary embodiment, in the light treatment operation, a duty ratio of a unit pulse of the light may become smaller, or an output of a unit pulse of the light in an on state or a high state may become gradually smaller.

[0028] According to the exemplary embodiment, the light filter may include a plurality of light filters, and configured to selectively allows a different range of wavelengths to pass through, and a wavelength range of the light emitted to the substrate may be selected by using any one of the light filters, depending on the type of organic matter residual on the substrate.

[0029] Still another exemplary embodiment of the present invention provides an apparatus for processing a substrate, the apparatus including: a liquid treatment chamber for liquid-treating a substrate by supplying an organic solvent to the substrate; a drying chamber for drying the substrate by supplying a supercritical fluid to the substrate treated in the liquid treatment chamber; and a light treatment chamber for irradiating the substrate treated in the drying chamber with light to remove an organic matter residual on the substrate, in which the light treatment chamber includes: a treatment housing having a treatment space in which the substrate is processed; a support member for supporting the substrate in the treatment space; and a light irradiation unit located on an upper side of the treatment housing and for irradiating the substrate supported on the support member with light, and the light irradiation unit includes: a xenon flash lamp for irradiating the substrate supported on the support member with light in the form of pulses, in which the xenon flash lamp is configured to generate light having wavelengths in the range of 300 to 1000 nm; a light source housing providing a space in which the xenon flash lamp is installed; a light filter configured to select wavelengths in the visible light range in the wavelengths of the light generated by the xenon flash lamp and allows the selected wavelengths to pass through; a reflective member installed on a top side of the xenon flash lamp, and for reflecting light generated by the xenon flash lamp toward the substrate; a middle plate disposed between the light source housing and the treatment housing, and having a middle plate refrigerant flow path formed therein; and a refrigerant supply unit for supplying the refrigerant, and the refrigerant supply unit includes: a refrigerant supply source for supplying a refrigerant; a first supply line for supplying the refrigerant from the refrigerant supply source to a reflective member refrigerant flow path formed in the reflective member; and a first delivery line for delivering the refrigerant from the reflective member refrigerant flow path to the middle plate refrigerant flow path.

[0030] According to the exemplary embodiment, the light irradiation unit may further include a light source tube in a shape of a tube surrounding the xenon flash lamp, a light source tube refrigerant flow path may be formed within the light source tube, and the refrigerant supply unit may include: a second supply line for supplying the refrigerant from the refrigerant supply source to the light source tube refrigerant flow path; and a third delivery line for delivering the refrigerant from the light source tube refrigerant flow path to a cooling plate refrigerant flow path of a cooling plate, in which the cooling plate is included in the treatment housing and located on a lower side of the support member.

[0031] According to the exemplary embodiment of the present invention, when a substrate is irradiated with light to remove residual organic matter on the substrate, the particles generated by the photodecomposition may be smoothly removed from the substrate.

[0032] The effect of the present invention is not limited to the foregoing effects, and those skilled in the art may clearly understand non-mentioned effects from the present specification and the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

[0033] FIG. **1** is a top plan view schematically illustrating a substrate processing apparatus according to an exemplary embodiment of the present invention.

[0034] FIG. **2** is a diagram schematically illustrating an exemplary embodiment of a liquid treatment chamber of FIG. **1**.

[0035] FIG. **3** is a diagram schematically illustrating an exemplary embodiment of a drying chamber of FIG. **1**.

[0036] FIG. **4** is a perspective view schematically illustrating an example of the second treatment module of FIG. **1**.

[0037] FIG. **5** is a planar cross-sectional view of a treatment housing of a light treatment chamber of FIG. **4**.

[0038] FIG. **6** is a flow chart schematically illustrating a substrate processing method according to an exemplary embodiment of the present invention.

[0039] FIG. **7** is a diagram illustrating a view of the substrate processing apparatus performing a liquid treatment operation of FIG. **6**.

[0040] FIG. **8** is a diagram illustrating a view of the substrate treatment apparatus performing a drying operation of FIG. **6**.

[0041] FIG. **9** is a diagram illustrating a view of the substrate treatment apparatus performing the light treatment operation of FIG. **6**.

[0042] FIG. **10** is a graph illustrating an example of a change in output of light over time when performing the light treatment operation of FIG. **9**.

[0043] FIG. **11** is a graph illustrating particle removal efficiency according to a range of wavelengths passing through a light filter.

[0044] FIG. **12** is a graph illustrating another example of a change in output of light over time when performing the light treatment operation of FIG. **9**.

[0045] FIG. **13** is a graph illustrating another example of a change in output of light over time when performing the light treatment operation of FIG. **9**.

[0046] FIG. **14** is a graph illustrating another example of a change in output of light over time when performing the light treatment operation of FIG. **9**.

[0047] FIG. **15** is a diagram illustrating a view of the substrate processing apparatus performing a cooling operation of FIG. **6**.

[0048] FIG. **16** is a perspective view schematically illustrating another example of a second treatment module of FIG. **1**.

[0049] FIG. **17** is a diagram illustrating a view of light source tubes that may be applied to a light irradiation unit of the present invention.

[0050] FIG. **18** is a diagram illustrating middle plates that may be applied to the light irradiation unit of the present invention.

[0051] FIG. **19** is a top plan view schematically illustrating a substrate processing apparatus according to another exemplary embodiment of the present invention.

[0052] FIG. **20** is a top plan view schematically illustrating a substrate processing apparatus according to another exemplary embodiment of the present invention.

DETAILED DESCRIPTION

[0053] Example embodiments will now be described more fully with reference to the accompanying drawings. Example embodiments are provided so that this disclosure will be thorough and will fully convey the scope to those who are skilled in the art. Numerous specific details are set forth such as examples of specific components, devices, and methods, to provide a thorough understanding of embodiments of the present disclosure. It will be apparent to those skilled in the art that specific details need not be employed, that example embodiments may be embodied in many different forms and that neither should be construed to limit the scope of the disclosure. In some example embodiments, well-known processes, well-known device structures, and well-known technologies are not described in detail.

[0054] The terminology used herein is for the purpose of describing particular example embodiments only and is not intended to be limiting. As used herein, the singular forms "a," "an," and "the" may be intended to include the plural forms as well, unless the context clearly indicates otherwise. The terms "comprises," "comprising," "including," and "having," are inclusive and therefore specify the presence of stated features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof. The method steps, processes, and operations described herein are not to be construed as necessarily requiring their performance in the particular order discussed or illustrated, unless specifically identified as an order of performance. It is also to be understood that additional or alternative steps may be employed.

[0055] When an element or layer is referred to as being "on," "engaged to," "connected to," or "coupled to" another element or layer, it may be directly on, engaged, connected or coupled to the other element or layer, or intervening elements or layers may be present. In contrast, when an element is referred to as being "directly on," "directly engaged to," "directly connected to," or "directly coupled to" another element or layer, there may be no intervening elements or layers present. Other words used to describe the relationship between elements should be interpreted in a like fashion (e.g., "between" versus "directly between," "adjacent" versus "directly adjacent," etc.). As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items.

[0056] Although the terms first, second, third, etc. may be used herein to describe various elements, components, regions, layers and/or sections, these elements, components, regions, layers and/or sections should not be limited by these terms. These terms may be only used to distinguish one element, component, region, layer or section from another region, layer or section. Terms such as "first," "second," and other numerical terms when used herein do not imply a sequence or order unless clearly indicated by the context. Thus, a first element, component, region, layer or section discussed below could be termed a second element, component, region, layer or section without departing from the teachings of the example embodiments.

[0057] Spatially relative terms, such as "inner," "outer," "beneath," "below," "lower," "above," "upper," and the like, may be used herein for ease of description to describe one element or feature's relationship to another element(s) or feature(s) as illustrated in the figures. Spatially relative terms may be intended to encompass different orientations of the device in use or operation in addition to the orientation depicted in the figures. For example, if the device in the figures is turned over, elements described as "below" or "beneath" other elements or features would then be oriented "above" the other elements or features. Thus, the example term "below" can encompass both an orientation of above and below. The device may be otherwise oriented (rotated 90 degrees or at other orientations) and the spatially relative descriptors used herein interpreted accordingly.

[0058] When the term "same" or "identical" is used in the description of example embodiments, it should be understood that some imprecisions may exist. Thus, when one element or value is referred to as being the same as another element or value, it should be understood that the element or value is the same as the other element or value within a manufacturing or operational tolerance range (e.g., ±10%).

[0059] When the terms "about" or "substantially" are used in connection with a numerical value, it should be understood that the associated numerical value includes a manufacturing or operational tolerance (e.g., ±10%) around the stated numerical value. Moreover, when the words "generally" and "substantially" are used in connection with a geometric shape, it should be understood that the precision of the geometric shape is not required but that latitude for the shape is within the scope of the disclosure.

[0060] Unless otherwise defined, all terms (including technical and scientific terms) used herein have the same meaning as commonly understood by one of ordinary skill in the art to which example embodiments belong. It will be further understood that terms, including those defined in commonly used dictionaries, should be interpreted as having a meaning that is consistent with their meaning in the context of the relevant art and will not be interpreted in an idealized or overly formal sense unless expressly so defined herein.

[0061] FIG. **1** is a top plan view schematically illustrating a substrate processing apparatus according to an exemplary embodiment of the present invention.

[0062] Referring to FIG. **1**, a substrate processing apparatus **1** includes an index module **10**, a first treatment module **20**, a second treatment module **30**, and a controller **40**. In one exemplary embodiment, the index module **10** and the first treatment module **20** are disposed along a first direction. Hereinafter, a direction in which the index module **10** and the first treatment module **20** are disposed is referred to as a first direction **92**, a direction perpendicular to the first direction **92** when looking at the substrate processing apparatus **1** from the top is referred to as a second direction **94**, and a direction perpendicular to both the first direction **92** and the second direction **94** is referred to as a third direction **96**.

[0063] The index module **10** transfers a substrate W, such as a wafer, from a container **80** in which the substrate W is accommodated to the first treatment module **20**, and accommodates the substrate W that has been processed in the first treatment module **20** to the container **80**. A longitudinal direction of the index module **10** is provided in the second direction **94**. The index module **10** includes a load port **12** and an index frame **14**. With respect to the index frame **14**, the load port **12** is located on the opposite side of the first treatment module **20**. The containers **80** in which the substrates W are placed on the load port **12**. A plurality of load ports **12** may be provided, and the plurality of load ports **12** may be disposed along the second direction **94**.

[0064] As the container **80**, an airtight container, such as a Front Open Unified Pod (FOUP), may be used. The container **80** may be placed on the load port **12** by a transfer means (not illustrated), such as an overhead transfer, an overhead conveyor, or an automatic guided vehicle, or an operator.

[0065] An index robot **120** is provided to the index frame **14**. A guide rail **140** of which a longitudinal is the second direction **94** is provided within the index frame **14**, and the index robot **120** may be provided to be movable on the guide rail **140**. The indexing robot **120** includes a hand **122** on which the substrate W is placed, and the hand **122** may be provided to be movable forward and backward, rotatable about the third direction **96**, and movable along the third direction **96**. The plurality of hands **122** is provided while being spaced apart from each other in the vertical direction, and is capable of independently moving forward and backward.

[0066] The first treatment module **20** includes a buffer unit **200**, a transfer chamber **300**, a liquid treatment chamber **400**, and a drying chamber **500**. The buffer unit **200** provides a space where the substrate W loaded into the first treatment module **20** and the substrate W unloaded from the first treatment module **20** temporarily reside. The liquid treatment chamber **400** performs a liquid treatment process of treating the substrate W with a liquid by supplying the liquid onto the substrate W. The drying chamber **500** performs a drying process of removing the liquid residual on the substrate W. The transfer chamber **300** transfers the substrate W between the buffer unit **200**, the liquid treatment chamber **400**, and the drying chamber **500**.

[0067] The transfer chamber **300** may be provided so that a longitudinal direction is the first direction **92**. The buffer unit **200** may be disposed between the index module **10** and the transfer chamber **300**. The liquid treatment chamber **400** and the drying chamber **500** may be disposed on the side portion of the transfer chamber **300**. The liquid treatment chamber **400** and the transfer chamber **300** may be disposed in the second direction **94**. The drying chamber **280** and the transfer chamber **300** may be disposed in the second direction **94**. The buffer unit **200** may be located at one end of the transfer chamber **300**.

[0068] According to the example, the liquid treatment chambers **400** are disposed on both sides of transfer chamber **300**, and the drying chambers **500** are disposed on both sides of the transfer chamber **300**, and the liquid treatment chambers **400** may be disposed closer to the buffer unit **200** than the drying chambers **500**. At one side of the transfer chamber **300**, the liquid treatment chambers **400** may be provided in an arrangement of A×B (each of A and B is 1 or a natural number larger than 1) in the first direction **92** and the third direction **96**. Further, at one side of the transfer chamber **300**, the drying chambers **500** may be provided in number of C×D (each of C and D is 1 or a natural number larger than 1) in the first direction **92** and the third direction **96**. Unlike the above, only the liquid treatment chambers **400** may be provided on one side of the transfer chamber **300**, and only the drying chambers **500** may be provided on the other side of the transfer chamber **300**.

[0069] The transfer chamber **300** includes a transfer robot **320**. A guide rail **340** having a longitudinal direction in the first direction **92** is provided in the transfer chamber **300**, and the transfer robot **320** may be provided to be movable on the guide rail **340**. The transfer robot **320** includes a hand **322** in which the substrate W is placed, and the hand **322** may be provided to be movable forward and backward, rotatable about the third direction **96**, and movable along the third direction **96**. The plurality of hands **322** is provided while being spaced apart from each other in the vertical direction, and is capable of independently moving forward and backward.

[0070] The buffer unit **200** includes a plurality of buffers **220** on which the substrate W is placed. The buffers **220** may be disposed while being spaced apart from each other in the third direction **96**. A front face and a rear face of the buffer unit **200** are opened. The front face is a face facing the index module **10**, and the rear face is a face facing the transfer chamber **300**. The index robot **120** may approach the buffer

unit **200** through the front face, and the transfer robot **320** may approach the buffer unit **200** through the rear face.

[0071] The second treatment module **30** may be installed on the index module **10**. The second treatment module **30** may be located with the load ports **12** of the index module **10** side by side. For example, the second treatment module **30** may be disposed with the load ports **12** in the second direction **94** side by side when the substrate processing apparatus **1** is viewed from the top. The second treatment module **30** may perform a light treatment on the substrate W. In addition, the second treatment module **30** may perform a cooling treatment on the substrate W.

[0072] The controller **70** may control the configurations of the substrate processing apparatus **1**. For example, the controller **40** may control configurations of the index module **10**, the first treatment module **20**, and the second treatment module **30**. Furthermore, the controller **40** controls the transfer robot **320** and the index robot **120** such that the processing of the substrate W occurs in a preset substrate processing order.

[0073] The controller **40** may include a process controller formed of a microprocessor (computer) that executes the control of the substrate processing apparatus **1**, a user interface formed of a keyboard in which an operator performs a command input operation or the like in order to manage the substrate processing apparatus **1**, a display for visualizing and displaying an operation situation of the substrate processing apparatus **1**, and the like, and a storage unit storing a control program for executing the process executed in the substrate processing apparatus **1** under the control of the process controller or a program, that is, a treating recipe, for executing the process in each component according to various data and treating conditions. Further, the user interface and the storage unit may be connected to the process controller. The treating recipe may be stored in a storage medium in the storage unit, and the storage medium may be a hard disk, and may also be a portable disk, such as a CD-ROM or a DVD, or a semiconductor memory, such as a flash memory.

[0074] FIG. **2** is a diagram schematically illustrating an exemplary embodiment of the liquid treatment chamber of FIG. **1**. Referring to FIG. **2**, the liquid treatment chamber **400** may liquid treat the substrate W by supplying the substrate W with a treatment liquid. The liquid treatment chamber **400** has a housing **410**, a cup **420**, a support unit **440**, a liquid supply unit **460**, and a lifting unit **480**. The housing **410** is provided in a generally rectangular parallelepiped shape. The cup **420**, the support unit **440**, and the liquid supply unit **460** are disposed in the housing **410**.

[0075] The cup **420** has a treatment space with an open top, and the substrate W is liquid-treated in the treatment space. The support unit **440** supports the substrate W in the treatment space. The liquid supply unit **460** supplies the liquid onto the substrate W supported by the support unit **440**. The liquid may be provided in a plurality of types, and may be sequentially supplied onto the substrate W. The lifting unit **480** adjusts a relative height between the cup **420** and the support unit **440**.

[0076] According to the example, the cup **420** includes a plurality of collection containers **422**, **424**, and **426**. Each of the collection containers **422**, **424**, and **426** has a collection space of collecting the liquid used for the treatment of the substrate. Each of the collection containers **422**, **424**, and **426** is provided in a ring shape surrounding the support unit **440**. When the liquid treatment process is in progress, the treatment liquid scattered by the rotation of the substrate W is introduced into the collection space through inlets **422*a***, **424*a***, and **426*a*** of the respective collection containers **422**, **424**, and **426**. According to the example, the cup **420** includes a first collection container **422**, a second collection container **424**, and a third collection container **426**. The first collection container **422** is disposed to surround the support unit **440**, the second collection container **424** is disposed to surround the first collection container **422**, and the third collection container **426** is disposed to surround the second collection container **424**. The second inlet **424*a***, which introduces the liquid into the second collection container **424**, may be located above the first inlet **422*a***, which introduces the liquid into the first collection container **422**, and the third inlet **426*a***, which introduces the liquid into the third collection container **426**, may be located above the second inlet **424*a***.

[0077] The support unit **440** includes a support plate **442** and a driving shaft **444**. An upper surface of the support plate **442** may be provided in a generally circular shape, and may have a diameter larger than a diameter of the substrate W. In the center portion of the support plate **442**, a support pin **442*a*** is provided to support the rear surface of the substrate W, and the support pin **442*a*** is provided with its upper end protruding from the support plate **442** so that the substrate W is spaced apart from the support plate **442** by a certain distance. A chuck pin **442*b*** is provided to an edge of the support plate **442**. The chuck pin **442*b*** is provided to protrude upward from the support plate **442**, and supports the lateral portion of the substrate W so that the substrate W is not separated from the support unit **440** when the substrate W is rotated. The driving shaft **444** is driven by a driver **446**, is connected to the center of the bottom surface of the substrate W, and rotates the support plate **442** with respect to the central axis thereof.

[0078] According to the example, the liquid supply unit **460** includes a first nozzle **462**, a second nozzle **464**, and a third nozzle **466**.

[0079] The first nozzle **462** supplies a first liquid onto the substrate W. The first liquid may be the liquid of removing a film or foreign substances residual on the substrate W.

[0080] The second nozzle **464** supplies a second liquid onto the substrate W. The second liquid may be the liquid well soluble in a third liquid. For example, the second liquid may be the liquid that is better soluble in the third liquid than the first liquid. The second liquid may be the liquid that neutralizes the first liquid supplied onto the substrate W. Further, the second liquid may be the liquid that neutralizes the first solution and at the same time is better soluble in the third solution than the first solution. According to one example, the second liquid may be water.

[0081] The third nozzle **466** supplies the third liquid onto the substrate W. The third liquid may be a liquid that is well soluble in the supercritical fluid used in the drying chamber **500**. For example, the third liquid may be a liquid that is more soluble in the supercritical fluid used in the drying chamber **500** than the second liquid. According to an example, the third liquid may be an organic solvent. The organic solvent may be isopropyl alcohol.

[0082] The first nozzle **462**, the second nozzle **464**, and the third nozzle **466** are supported on different arms **461**, and the arms **461** may be moved independently. Optionally, the first

nozzle **462**, the second nozzle **464**, and the third nozzle **466** may be mounted to the same arm and moved at the same time.

[0083] The lifting unit **480** moves the cup **420** in the vertical direction. By the vertical movement of the cup **420**, a relative height between the cup **420** and the substrate W is changed. This changes the collection containers **422**, **424**, and **426** for collecting the treatment liquid according to the type of liquid supplied to the substrate W, so that the liquids may be collected separately. Unlike the description, the cup **420** may be fixedly installed, and the lifting unit **480** may move the support unit **440** in the vertical direction.

[0084] FIG. **3** is a diagram schematically illustrating an exemplary embodiment of the drying chamber of FIG. **1**. The drying chamber **500** may provide a supercritical fluid to the substrate W that has been liquid treated in the liquid treatment chamber **400** to dry treat the substrate W. According to the exemplary embodiment, the drying chamber **500** removes the liquid on the substrate W by using a supercritical fluid. The drying chamber **500** includes a body **520**, a support body **540**, a fluid supply unit **560**, and a blocking plate **580**.

[0085] The body **520** provides an interior space **502** in which the drying process is performed. The body **520** includes an upper body **522** and a lower body **524**, and the upper body **522** and the lower body **524** are combined with each other to provide the interior space **502** described above. The upper body **522** is provided above the lower body **524**. The upper body **522** is fixed in position, and the lower body **524** may be raised and lowered by a drive member **590**, such as a cylinder. When the lower body **524** is spaced apart from the upper body **522**, the interior space **502** is opened, and in this case, the substrate W is loaded or unloaded. During the process, the lower body **524** is in close contact with the upper body **522**, so that the interior space **502** is sealed from the outside.

[0086] The drying chamber **500** includes a heater **570**. According to one example, the heater **570** is located inside the wall of the body **520**. The heater **570** heats the interior space **502** of the body **520** so that the fluid supplied into the interior space of the body **520** maintains a supercritical state.

[0087] The support body **540** supports the substrate W in the interior space **502** of the body **520**. The support body **540** includes a fixing rod **542** and a cradle **544**.

[0088] The fixing rod **542** is fixedly installed on the upper body **522** so as to protrude downward from the bottom surface of the upper body **522**. The fixing rod **542** is provided so that a longitudinal direction thereof is the vertical direction. A plurality of fixing rods **542** is provided and is positioned to be spaced apart from each other. The fixing rods **542** are disposed so that the substrate W does not interfere with the fixing rods **542** when the substrate W is loaded into or unloaded from the space surrounded by the fixing rods **542**. The cradle **544** is coupled to each of the fixing rods **542**.

[0089] The cradle **544** extends from the lower end of the fixing rod **542** toward the space surrounded by the fixing rods **542**. Due to the above-described structure, the substrate W loaded into the interior space **502** of the body **520** has the edge region placed on the cradle **544**, and the entire top surface area of the substrate W, a center region of the bottom surface area of the substrate W, and a portion of the edge region of the bottom surface of the substrate W are exposed to the drying fluid supplied to the interior space **502**.

[0090] The fluid supply unit **560** supplies a drying fluid to the interior space **502** of the body **520**. According to the example, the drying fluid may be supplied to the interior space **502** in a supercritical state. In contrast, the drying fluid may be supplied to the interior space **502** in a gaseous state and phase change to a supercritical state within the interior space **502**. According to the example, the fluid supply unit **560** includes a main supply line **562**, an upper branch line **564**, and a lower branch line **566**.

[0091] The upper branch line **564** and the lower branch line **566** are branched from the main supply line **562**. The upper branch line **564** is coupled to the upper body **522** to supply drying fluid from the top of the substrate W placed on the support **540**. According to the example, the upper branch line **564** is coupled to the center of the upper body **522**.

[0092] The lower branch line **566** is coupled to the lower body **524** to supply a drying fluid from the lower portion of the substrate W placed on the support **540**. According to the example, the lower branch line **566** is coupled to the center of the lower body **524**. An exhaust line **550** is coupled to the lower body **524**. The supercritical fluid in the interior space **502** of the body **520** is exhausted to the outside of the body **520** through the exhaust line **550**.

[0093] A blocking plate **580** may be disposed in the interior space **502** of the body **520**. The blocking plate **580** may be provided in a disk shape. The blocking plate **580** is supported by a support **582** so as to be spaced upward from the bottom surface of the body **520**. The support **582** is provided in a rod shape, and a plurality of supports **582** is arranged to be spaced apart from each other by a predetermined distance. When viewed from above, the blocking plate **580** may be provided to overlap the outlet of the lower branch line **566** and the inlet of the exhaust line **550**. The blocking plate **580** may prevent drying fluid supplied through the lower branch line **566** from being discharged directly toward the substrate W and damaging the substrate W.

[0094] FIG. **4** is a perspective view schematically illustrating an example of the second treatment module of FIG. **1**. Referring to FIG. **4**, the second treatment module **30** includes a light treatment chamber **600** and a cooling chamber **800**.

[0095] The light treatment chamber **600** irradiates the substrate W dried in the drying chamber **500** with light by using a supercritical fluid to remove any residual organic matter on the substrate W. The organic matter may be a material that is not completely removed from the substrate W in the drying process and remains. Alternatively, the organic matter may be the material generated when the substrate W is treated with a supercritical fluid. The cooling chamber **800** cools the light-treated substrate W in the light treatment chamber **600**. The light treatment chamber **600** and the cooling chamber **800** are disposed to be stacked with each other. According to the example, the light treatment chamber **600** is located at the upper side of the cooling chamber **800**. In contrast, the light treatment chamber **600** may be disposed downstream of the cooling chamber **800**. Optionally, the light treatment chamber **600** may be disposed to the side of the cooling chamber **800**. The light treatment chamber **600** and the cooling chamber **800** may each be provided. Optionally, at least one of the light treatment chamber **600** and the cooling chamber **800** may be provided in plurality.

[0096] In the following, the light treatment chamber **600** is described. FIG. **5** is a planar cross-sectional view of a treatment housing of the light treatment chamber of FIG. **4**.

[0097] Referring to FIGS. **4** and **5**, the light treatment chamber **600** may include a treatment housing **610**, a gas distribution plate **620**, a gas supply unit **630**, a gas exhaust unit **640**, a light irradiation unit **650**, a refrigerant supply unit **660**, and a support member **670**.

[0098] The treatment housing **610** may provide a space in which the substrate W is processed. The treatment housing **610** may provide a treatment space **613** where the substrate W is light-treated. The treatment housing **610** may include a housing body **611**, a cooling plate **612**, and a door **615**.

[0099] The housing body **611** may have a barrel shape with an open bottom. An opening may be formed in the upper center region of the housing body **611**. On the lower side of the housing body **611**, the cooling plate **612** may be installed. In the opening formed in the upper center region of the housing body **611**, a middle plate **652** to be described later may be inserted. The housing body **6112**, the cooling plate **612**, and the middle plate **652** to be described later may be combined with each other to define the treatment space **613**.

[0100] The inlet may be formed on one side of the housing body **611**. The inlet **614** may be opened and closed by a door **615** mounted on the exterior of the housing body **611**. The inlet **614** may be formed at a location facing the index robot **120** described above. While the substrate W is being light-treated, the door **615** may close the inlet **614**. When the substrate W is loaded into or unloaded from the light treatment chamber **600**, the door **615** may open the inlet **614**.

[0101] The cooling plate **612** installed on the lower side of the housing body **611** may minimize the transfer of heat generated by the light-treatment of the substrate W, or heat generated by the light emitted by the light source **653**, to the cooling chamber **800** located on the lower side of the light treatment chamber **600**. A cooling plate refrigerant flow path **612*a*** may be formed in the cooling plate **612**. In the cooling plate refrigerant flow path **612*a***, refrigerant supplied by the refrigerant supply unit **660** described later may flow.

[0102] The gas distribution plate **620** helps to ensure that the treatment space **613** is uniformly supplied with gas supplied by the gas supply unit **630**. The gas distribution plate **620** may be installed in the treatment space **613**. The gas distribution plate **620** may be installed to face an inner wall of the treatment housing **610**. The gas distribution plate **620** may include a gas supply plate **621** and a gas exhaust plate **622**.

[0103] The gas supply plate **621** may be installed to face the gas supplied by a gas supply line **633** of the gas supply unit **630** described later. Supply holes **621*a*** may be formed in the gas supply plate **621**. Gas supplied by the gas supply unit **630**, which will be described below, may be introduced into the treatment space **613** through the supply holes **621*a*** of the gas supply plate **621**.

[0104] The gas exhaust plate **622** may be installed to face the inlet **614** formed in the treatment housing **610**. Exhaust holes **622*a*** may be formed in the gas exhaust plate **622**. The gas exhaust plate **622** may be installed in a symmetrical position relative to the gas supply plate **621**, with respect to the center of the treatment space **613**.

[0105] The gas supplied by the gas supply unit **630** may be exhausted sequentially through the gas supply plate **621**, the treatment space **613**, and the gas exhaust plate **622**. That is, in the treatment space **613**, an air current is formed along the first direction X by the gas supplied by the gas supply unit **630**, and the air current may serve to discharge the organic matter that is decomposed and/or removed from the substrate W to the outside.

[0106] The gas supply unit **630** may supply gas to the treatment space **613**. The gas supplied by the gas supply unit **630** may be inert gas. For example, the gas supplied by the gas supply unit **630** may be nitrogen, or inert gas, such as argon. The gas supply unit **630** may include a gas supply source **631**, a gas supply valve **632**, and the gas supply line **633**.

[0107] The gas supply source **631** may be a supply source that stores and/or supplies the inert gas described above. The gas supply source **631** may be a gas storage tank that stores and/or supplies inert gas. The gas supply source **631** may be connected to the gas supply line **633**. The gas supply valve **632** is installed in the gas supply line **633**, which may control whether the gas supply unit **630** supplies gas and/or the gas supply flow rate per unit time. The gas supply valve **632** may be a flow control valve, or may be an open/close valve.

[0108] The gas supply line **633** may be connected to the gas supply source **631** and the treatment housing **610**. The gas supply line **633** may be connected to a sidewall of the treatment housing **610**. The gas supply line **633** may supply gas to the space between the treatment housing **610** and the gas supply plate **621**. The inert gas supplied by the gas supply line **633** may be introduced into the treatment space **613** via the gas supply plate **621**.

[0109] The gas exhaust unit **640** may exhaust the gas supplied by the gas supply unit **630**. The gas exhaust unit **640** may include a gas exhaust line **642**, and a gas exhaust valve **643**. The gas exhaust line **642** may be connected to an exhaust device (not shown), such as a pump. The exhaust device may generate depressurization, and the depressurization generated by the exhaust device may exhaust the gas supplied to the treatment space **613**. The gas exhaust line **642** may be connected between the gas exhaust plate **622** and the inner wall of the treatment housing **610**. The gas exhaust line **642** may be connected between the inner wall of the treatment housing **610**, in which the inlet **614** is formed, and the gas exhaust plate **622**.

[0110] The gas exhaust valve **643** may control whether the gas exhaust unit **640** exhausts gas and/or the gas exhaust flow rate per unit time. The gas exhaust valve **643** may be a flow control valve, or may be an open/close valve.

[0111] The gas supplied by the gas supply unit **630** may be introduced into the treatment space **613** via the gas supply plate **621**, and the gas introduced into the treatment space **613** may be discharged to the outside through the gas exhaust unit **640** via the gas exhaust plate **622**. The location where the gas is supplied and the location where the gas is exhausted face each other when looking at the treatment space **613** from the top. Thus, in the treatment space **613**, air current occurs by the gas flowing along the first direction **92**. The air current discharges the organic matter being removed from the substrate W to the outside of the light treatment chamber **600**.

[0112] The light irradiation unit **650** may irradiate the substrate W supported in the treatment space **613** with light. The light irradiation unit **650** may irradiate the substrate W with light in the form of pulses. The light irradiation unit **650** may irradiate the substrate W with light having wavelengths in the visible light range.

[0113] The light irradiation unit **650** may include a light source housing **651**, a middle plate **652**, a light source **653**, a light source controller **653***a*, a reflective member **654**, a light source tube **655**, air supply modules **656***a*, **656***b*, and **656***c*, and air exhaust modules **657***a* and **657***b*.

[0114] The light source housing **651** may have a barrel shape with an open bottom. The light source housing **651** may be located on top of the treatment housing **610**. The light source housing **651** may define a light source placement space in which the light source **653** may be placed. The light source housing **651** may be combined with the middle plate **652** to define a light source placement space. The light source housing **651** may be formed with a smaller width in the first direction X than the treatment housing **610**.

[0115] On the bottom side of the light source housing **651**, a middle plate **652** may be installed. The middle plate **652** may have a plate shape. The middle plate **652** may be disposed between the light source housing **651** and the treatment housing **610**. The middle plate **652** may compartmentalize the treatment space **613** and the light source placement space of the light source housing **651** from each other. The middle plate **652** may be formed of a transparent material to allow light generated by the light source **653** to pass through. For example, the middle plate **652** may be formed of a transparent quartz material. Additionally, the middle plate **652** may have a middle plate refrigerant flow path **652***a* formed through which refrigerant supplied by the refrigerant supply unit **660**, described later, may flow.

[0116] The light source **653** may generate light that is emitted onto the substrate W. The light source **653** may irradiate the substrate W with light to remove residual organic matters on the substrate W. The light source **653** may be a flash lamp. The light source **653** may be a xenon flash lamp. The light source **653** may generate glare. The light source **653** may generate light in the form of pulses. The reason the light source **653** generates light in the form of pulses is that the light source **653** is capable of irradiating the substrate W with light that is generated at a greater output (that is, has greater energy) even though consuming the same power.

[0117] For example, when the light source **653** generates light in the form of pulses, the light source **653** may include an on state and an off state. The on state and the off state may be repeated. The on state may be a state in which the light source **653** generates light, and the off state may be a state in which the light source **653** does not generate light. Additionally, when the light source **653** generates light in the form of pulses, the light source **653** may include a high state and a low state. The high state may be a state in which the output of the light generated by the light source **653** is large, and the low state may be a state in which the output of the light generated by the light source **653** is small.

[0118] Assuming the same power is consumed, when the light source **653** generates light in the form of pulses, the light may have a higher output peak when the light source **653** is in the on or high state, compared to when the light source **653** generates light continuously. Thus, when the light source **653** generates light in the form of pulses, it has the advantage of effectively removing organic matter on the substrate W even though the light source **653** consumes the same power.

[0119] Additionally, the light source **653** may have a generally rod shape. A longitudinal direction of the light source **653** may be parallel to the second direction **94**. Additionally, a plurality of light sources **653** may be installed. Two light sources **653** may be installed. The light sources **653** may be disposed side-by-side along the first direction **92**.

[0120] Additionally, the light source **653** may be configured to generate light in the full wavelength range (300 to 1000 nm), which includes the visible light wavelength range, the infrared wavelength range, and the ultraviolet wavelength range.

[0121] The light source controller **653***a* may control the operation of the light source **653**. The light source controller **653***a* may be configured to control at least one of an output of light generated by the light source **653**, a duty ratio in a unit pulse of light, and a period of a unit pulse of light. The light source controller **653***a* may include a processor, circuit elements, and the like that may control the operation of the light source **653**.

[0122] The reflective member **654** may reflect light emitted by the light source **653**. The reflective member **654** may reflect light traveling upward from the light source **653** in a direction toward the substrate W. The reflective member **654** may have a plate shape with a longitudinal second direction **94**, with both ends bent toward the light source **653**. The reflective member **654** may be installed on top of the light source **653**. The reflective member **654** may have a reflective film attached that may reflect light emitted by the light source **653**, or may be coated with a reflective component that may reflect light. In addition, the reflective member **654** may have a reflective member refrigerant flow path **654***a* formed through which refrigerant supplied by the refrigerant supply unit **660**, described later, may flow.

[0123] The light source tube **655** may have a shape that surrounds the light source **653**. The light source tube **655** may have a tube shape into which the rod-shaped light source **653** may be inserted. For example, the light source tube **655** may have a tube shape with a perforated center region in the same direction as the length direction of the light source **653**. The light source **653** may be inserted into the light source tube **655**.

[0124] The light source tube **655** may be formed of a transparent material to allow light generated by the light source **653** to be transmitted. For example, the light source tube **655** may be formed of a transparent quartz material. Within the light source tube **655**, a light source tube refrigerant flow path **655***a* may be formed through which refrigerant supplied by the refrigerant supply unit **660** described later may flow. Refrigerant flowing in light source tube refrigerant flow path **655***a* may cool the light source **653**. Thus, the temperature of the light source **653** may be prevented from becoming excessively high.

[0125] Additionally, an inner surface of the light source tube **655** that is in contact with the light source **653** and/or an outer surface of the light source tube **655** may have a light filter film attached to selectively allow a set range of wavelengths of light generated by the light source **653** to pass through. In contrast, the inner surface in contact with the light source **653** and/or the outer surface of the light source tube **655** may be coated with a coating layer to selectively allow a set range of wavelengths of light generated by the light source **653** to pass through. In this case, the light source tube **655** may function as a light filter that selects a set range of wavelengths of light generated by the light source **653** and allows the wavelengths to pass through.

[0126] The light source tube **655** may be configured to selectively pass wavelengths in the visible light range. For example, the light source tube **655** may be configured to selectively pass wavelengths in the range of 350 to 700 nm.

[0127] Air supply modules **656***a*, **656***b*, and **656***c* may supply temperature- and humidity-controlled Clean Dry Air (CDA) to a space within the light source housing **651**. The air supply modules **656***a*, **656***b*, and **656***c* may include an air supply source **656***a* that supplies CDA, an air supply line **656***b* that supplies CDA from the air supply source **656***a* to the light source housing **651**, and an air supply valve **656***c* that is installed in the air supply line **656***b*.

[0128] The air exhaust modules **657***a* and **657***b* may exhaust the CDA supplied into the space within the light source housing **651**. The air exhaust modules **657***a* and **657***b* may include an air exhaust line **657***b* connected to the light source housing **651**, and an air exhaust valve **657***a* installed in the air exhaust line **657***b*.

[0129] The refrigerant supply unit **660** may supply refrigerant to the components of the light treatment chamber **600** to inhibit the temperature of the light treatment chamber **600** from increasing. When the light source **653** in the light treatment chamber **600** continuously generates light, the energy carried by the light may be accumulated and cause the temperature of the components in the light treatment chamber **600** to become excessively high. The refrigerant supply unit **660** may supply a refrigerant, such as coolant or cooling gas, to the components of the light treatment chamber **600** to inhibit the temperature of the light treatment chamber **600** from increasing.

[0130] The refrigerant supply unit **660** may include a refrigerant supply source **661**, a refrigerant supply line **662**, a first supply line **663**, a second supply line **664**, a first delivery line **665**, a second delivery line **666**, a third delivery line **667**, a first refrigerant discharge line **668***a*, a second refrigerant discharge line **668***b*, and a main refrigerant discharge line **669**. Further, the refrigerant supply unit **660** may include a refrigerant supply valve **662***a* installed in the refrigerant supply line **662**, and a refrigerant discharge valve **669***a* installed in the main refrigerant discharge line **669**. Each of the valves **662***a* and **669***b* may control the supply and discharge of the refrigerant. Additionally, each of the valves **662***a*, **669***b* may be provided as an open/close valve or a flow control valve.

[0131] The refrigerant supply source **661** may be a refrigerant storage tank storing the coolant or cooling gas described above. The refrigerant supply source **661** may be configured to store and/or supply refrigerant. The refrigerant stored in the refrigerant supply source **661** may be supplied to the components of the light treatment chamber **600** via the refrigerant supply line **662**. The refrigerant supply line **662** may branch into a first supply line **663** and a second supply line **664**.

[0132] The first supply line **663** may supply refrigerant to the reflective member refrigerant flow path **654***a*. The refrigerant flowing in the reflective member refrigerant flow path **654***a* may prevent the temperature of the reflective member **654** from becoming excessively high. The reflective member refrigerant flow path **654***a* may be connected to the first delivery line **665**. The first delivery line **665** may be connected to the middle plate refrigerant flow path **652***a*. The refrigerant flowing in the middle plate refrigerant flow path **654***a* may prevent the temperature of the middle plate **652** from becoming excessively high.

[0133] The middle plate refrigerant flow path **654***a* may be connected to the first refrigerant discharge line **668***a*. The first refrigerant discharge line **668***a* may be connected to the main refrigerant discharge line **669**. The refrigerant delivered to the main refrigerant discharge line **669** may be discharged to the outside of the substrate processing apparatus **1**, or may be circulated and delivered to the refrigerant supply source **661**.

[0134] The second supply line **664** may supply refrigerant to the light source tube refrigerant flow path **655***a* of any one of the light source tubes **655**. The second delivery line **666** may be connected to the light tube refrigerant flow path **655***a* of any one of the light source tubes **655** and the light tube refrigerant flow path **655***a* of another of the light source tubes **655**. The second delivery line **666** may deliver refrigerant from the light tube refrigerant flow path **655***a* of any one of the light source tubes **655** to the light tube refrigerant flow path **655***a* of another of the light source tubes **655**. The refrigerant flowing in the light source tube refrigerant flow path **655***a* may prevent the temperature of the light source tube **655** from becoming excessively high, and may also prevent the temperature of the light source **653** from becoming excessively high.

[0135] The light source **653** heats the substrate W by the energy delivery manner using light, rather than the method of directly emitting heat and heating the substrate W. Thus, the light source **653** is cooled by the light source tube **655**, so that the efficiency of removing organic matter adhering to the substrate W is not reduced.

[0136] The third delivery line **667** may deliver refrigerant from the light source tube refrigerant flow path **655***a* of another of the light source tubes **655** to the cooling plate refrigerant flow path **612***a*. The refrigerant flowing in the cooling plate refrigerant flow path **612***a* lowers the temperature of the cooling plate **612**. In addition, the cooling plate **612** may minimize the delivery of heat generated during the process of processing the substrate W to the cooling chamber **800**.

[0137] The cooling plate refrigerant flow path **612***a* may be connected to the second refrigerant discharge line **668***b*. The second refrigerant discharge line **668***b* may be connected to the main refrigerant discharge line **669**. The refrigerant delivered to the main refrigerant discharge line **669** may be discharged to the outside of the substrate processing apparatus **1**, or may be circulated and delivered to the refrigerant supply source **661**.

[0138] The support member **670** may support the substrate W. The support member **670** may be configured to support the bottom surface of the substrate W. The support member **670** may also be referred to as a substrate holder. The support member **670** may be configured to support a bottom edge region of the substrate W.

[0139] The following describes the cooling chamber **800**.

[0140] Referring again to FIG. **4**, the cooling chamber **800** may include a cooling housing **810**, a gas injection plate **820**, a cooling gas supply unit **830**, and a support shelf **840**.

[0141] The cooling chamber **800** may provide a cooling treatment for the substrate W. The cooling chamber **800** may cool the substrate W that has been light-treated in the light treatment chamber **600**.

[0142] The cooling housing **810** may have a barrel shape with open sides. For example, the cooling housing **810** may

have a barrel shape with an open side facing the index robot **120**. The cooling housing **810** may define a cooling space **812**.

[0143] The gas injection plate **820** may be installed in the cooling space **812**. The gas injection plate **820** may have injection holes **820***a*.

[0144] The cooling gas supply unit **830** may supply cooling gas to the cooling space **812**. The cooling gas may be inert gas. For example, the cooling gas may be inert gas, such as nitrogen or argon. The cooling gas supply unit **830** may include a cooling gas supply source **831**, a cooling gas supply line **832**, and a cooling gas supply valve **833**.

[0145] The cooling gas supply source **831** may supply and/or store inert gas. The cooling gas supply source **831** may be a gas storage tank that stores the inert gas. In some cases, the cooling gas supply source **831** and the gas supply source **631** described above may be the same configuration. The inert gas supplied by the cooling gas supply source **831** may be supplied to the cooling space **812** via the cooling gas supply line **832**. The cooling gas may be supplied to the space between the cooling housing **810** and the gas injection plate **820**. The cooling gas supply valve **833** installed in the cooling gas supply line **832** may regulate whether to supply cooling gas to the cooling space **812**, or the supply flow rate per unit time. The cooling gas supply valve **833** may be an open/close valve, or may be provided as a flow control valve.

[0146] The support shelf **840** may support the substrates W. The support shelf **840** may support the substrates W which have been completely light-treated in the light treatment chamber **600**. The support shelf **840** may have the same or similar shape as the support member **670** described above. The plurality of support shelves **840** may be installed in the cooling space **812** along the third direction **96**.

[0147] On the other hand, a side portion of the cooling housing **810** may be open. The open portion of the cooling housing **810** may be opposite to the portion on which the gas injection plate **820** is installed. The cooling gas supplied through the gas injection plate **820** may form a continuous or intermittent air current along the first direction **92**. The cooling gas may minimize particles that may be suspended in the index module **10** from being introduced into the cooling space **812**. Furthermore, since the substrates W that are loaded into the cooling housing **810** are the substrates W that have been stripped of organic matter in the light treatment chamber **600**, the possibility of contamination of the cooling space **812** by organic matter adhering to the substrates W is very low.

[0148] FIG. **6** is a flow chart schematically illustrating a substrate processing method according to an exemplary embodiment of the present invention.

[0149] Referring to FIG. **6**, a substrate processing method according to an exemplary embodiment of the present invention may include a liquid treatment operation S**10**, a drying operation S**20**, a light treatment operation S**30**, and a cooling operation S**40**. The above operations may be performed sequentially. Further, in order to perform each operation, the transfer robot **320** and the index robot **120** provided by the substrate processing apparatus **1** may transfer the substrate W sequentially. For example, the transfer robot **320** and the index robot **120** may sequentially transfer the substrate W to the liquid treatment chamber **400**, the drying chamber **500**, the light treatment chamber **600**, and the cooling chamber **800**. The substrates W cooled in the cooling chamber **800** may be transferred by the index robot **120** to the container **80** placed on the load port **12** and unloaded to the outside of the substrate processing apparatus **1**.

[0150] FIG. **7** is a diagram illustrating a view of the substrate processing apparatus performing the a liquid treatment operation of FIG. **6**.

[0151] Referring to FIGS. **6** and **7**, the liquid treatment operation S**10** may include liquid treatment of the substrate W by supplying a treatment liquid TL to the substrate W rotating in the liquid treatment chamber **400**. The treatment liquid TL may be a rinse liquid, such as pure water, or an organic solvent, such as IPA. FIG. **7** illustrates the case where the third nozzle **466** supplies an organic solvent as an example. In addition, the liquid treatment chamber **400** may sequentially supply a rinse liquid and an organic solvent to clean the substrate W. The rinse liquid may clean the substrate W. When the rinse liquid is pure water, it may be difficult to remove the rinse liquid that has penetrated between the patterns on the substrate W due to the relatively high surface tension of pure water. Therefore, when the rinse solution is supplied to the substrate W and then an organic solvent is additionally supplied, the rinse solution on the substrate W may be replaced by an organic solvent with relatively low surface tension. When the organic solvent is IPA, the surface tension of IPA is relatively low and may be easily removed from the substrate W.

[0152] FIG. **8** is a diagram illustrating a view of the substrate treatment apparatus performing the drying operation of FIG. **6**.

[0153] Referring to FIGS. **6** and **8**, in the drying operation S**20**, the substrate W may be dry treated by supplying a supercritical fluid SF to the liquid-treated substrate W in the drying chamber **500**. The substrate W may be loaded into to the drying chamber **500** with a liquid film formed by the organic solvent on the substrate W. The supercritical fluid SF may be carbon dioxide gas in a supercritical state. The supercritical fluid SF may dry the liquid film formed on the substrate W. In addition, because the supercritical fluid SF has very good penetration into the patterns formed on the substrate W, the supercritical fluid SF may very effectively remove the treatment liquid TL remaining on the substrate W.

[0154] FIG. **9** is a diagram illustrating a view of the substrate treatment apparatus performing the light treatment operation of FIG. **6**.

[0155] Referring to FIGS. **6** and **9**, the light treatment operation S**30** may be performed after the drying operation S**20** is performed. The substrate W dried in the drying chamber **500** may be loaded into the light treatment chamber **600**. The light source **653** in the light treatment chamber **600** may generate light LI. The light LI in a set range of wavelengths may be selected by the light source tube **655**, which may be a light filter. The light LI selected with the set range of wavelength may be transmitted to the substrate W. The set range of wavelength may be wavelengths in the visible light range. For example, the set range of wavelength may be wavelengths in the range of 350 to 700 nm. When the light LI is transmitted to the substrate W, the organic matter adhering to the substrate W may be thermally degraded. The thermally degraded organic matter may be sublimated or vaporized into the treatment space **613**. The sublimated or vaporized organic matter may be discharged

to the outside via the gas exhaust unit **640** in an air current generated by the gas supplied by the gas supply unit **630**.

[0156] FIG. **10** is a graph illustrating an example of a change in output of light over time when performing the light treatment operation of FIG. **9**.

[0157] Referring to FIGS. **9** and **10**, the light LI emitted by the light source **653** may be in the form of pulses. The on state and the off state of the light source **653** may be repeated periodically, and the on state and the off state corresponding to one period may be defined as a unit pulse. In addition, for the pulse form, the light source **653** may periodically repeat a high state and a low state, where one period of high and low states may be defined as a unit pulse. When the light LI is emitted in the form of a pulse, it may mean that the unit pulse is repeated at least once (for example, multiple times).

[0158] The on state of the light source **653** may mean a state in which the light L**1** is output, the off state may mean a state in which the light L**1** is not output (output is zero), a high state of the light source **653** may mean a state in which the light L**1** is output but the output value is large, and a low state of the light source **6553** may mean a state in which the light L**1** is output but the output value is smaller than the high state.

[0159] As discussed above, when the light source **653** emits the light in the form of a pulse, the light source **653** may have a higher output peak of the light LI, assuming that the light source **653** consumes the same power, which has the advantage of effectively removing the organic matter on the substrate W.

[0160] Further, the light source controller **653*a*** may be configured to control a duty ratio in a unit pulse of light generated by the light source **653**. The duty ratio may refer to the rate at which the light source **653** maintains an on or high state per one period T. For example, the duty ratio may be defined as Ton/T.

[0161] Further, the light source controller **653*a*** may adjust the length of the period T of the unit pulse of the light LI generated by the light source **653**. For example, the light source controller **653*a*** may shorten or lengthen the period T.

[0162] Additionally, the light source controller **653*a*** may increase or decrease the output of the light LI generated by the light source **653**.

[0163] FIG. **10** shows an example in which the substrate W is light-treated by setting the output of the light LI in the on state to a first output P**1**, a duty ratio to 50%, and the period to T.

[0164] FIG. **11** is a graph illustrating particle removal efficiency according to a range of wavelengths passing through a light filter.

[0165] FIG. **11** shows the results of an organic matter (particle) removal experiment on the substrate W in the case [No] where no light filter is used, the case [UV Pass] where the light filter allows the wavelengths in the ultraviolet range to pass, the case [VIS Pass] where the light filter allows the wavelengths in the visible light range to pass, and the case [IR Pass] where the light filter allows the wavelengths in the infrared range to pass, in which a xenon flash lamp as described above is used as the light source **653**. In each case, the left side shows the number of particles before light treatment and the right side shows the number of particles after light treatment.

[0166] Referring to FIG. **11**, it can be seen that the best organic removal efficiency is achieved when no light filter is used (when the substrate is irradiated with the light LI in the full wavelength range) and when the light filter allows the wavelengths in the visible light range to pass through (when the substrate is irradiated with the light LI in the visible wavelength range). When the substrate was irradiated with the light LI of all wavelengths, the organic matter removal efficiency was 43.6%, and when the substrate was irradiated with the light LI of the wavelengths in the visible light range, the organic matter removal efficiency was 41.4%.

[0167] However, when the light filter is applied, the case where the light filter allows the wavelengths in the visible light range to pass through (when the light LI of the wavelength in the visible light range is emitted to the substrate) may be most efficient to remove the organic matter.

[0168] Specifically, when a light filter is not used (when the light LI of all wavelengths is emitted to the substrate), the temperature of the substrate W rises to the level of 350° C. In this case, the substrate W may be warped or the substrate may be broken due to thermal deformation and the like. The inventor has confirmed through long experiments that such an increase in temperature of the substrate W is caused by the wavelengths in the infrared range.

[0169] On the other hand, when the light filter that allows the wavelengths in the visible light range to pass through is used (when the substrate is irradiated with the light LI of the wavelengths in the visible light range), the temperature of the substrate W rises only to the level of 280° C. In this case, it is possible to minimize the occurrence of the warpage phenomenon or the broken phenomenon of the substrate described above.

[0170] In short, the present invention has the advantage of increasing organic matter removal efficiency by emitting the light LI in the form of pulses, and maintaining organic matter removal efficiency for the substrate W while preventing the temperature of the substrate W from increasing excessively.

[0171] FIG. **12** is a graph illustrating another example of a change in output of light over time when performing the light treatment operation of FIG. **9**.

[0172] Referring to FIGS. **6**, **8**, and **12**, the light source controller **653*a*** of the present invention may control the light source **653** such that the output gradually decreases from a first output P**1**, to a second output P**2**, and to a third output P**3**, in the on state or high state of the unit pulse of the light LI during the light treatment of the substrate W. When the substrate W is repeatedly irradiated with the light LI, thermal energy may be accumulated in the substrate W. This may cause the temperature of the substrate W to increase excessively. Furthermore, when the light treatment of the substrate W is completed, the substrate W is cooled in the cooling chamber **800**, and when the temperature of the substrate W changes too rapidly during the cooling process, the substrate W may be warped or broken. Accordingly, the present invention may solve the above problem by making the output gradually smaller from the first output P**1** to the second output P**2**, and to the third output P**3** in the on or high state of the unit pulse of the light LI during the light treatment of the substrate W.

[0173] FIG. **13** is a graph illustrating another example of a change in output of light over time when performing the light treatment operation of FIG. **9**.

[0174] Referring to FIGS. **6**, **8**, and **13**, the light source controller **653*a*** of the present invention may control the light source **653** to gradually decrease the on-duty ratio of

the unit pulse of the light LI during the light treatment of the substrate W. For example, the on-duty ratio may gradually decrease from a level of Ton**1**/T=50%, to a level of Ton**2**/T=40%, and then to a level of Ton**3**/T=30% (in FIGS. **13**, Ton**1**, Ton**2**, and Ton**3** are shown as being repeated once each for ease of description, but Ton**1**, Ton**2**, and Ton**3** may each be repeated a plurality of times). In this case, it is also advantageous to minimize an excessive increase in the temperature of the substrate W and a sudden change in the temperature of the substrate W.

[0175] FIG. **14** is a graph illustrating another example of a change in output of light over time when performing the light treatment operation of FIG. **9**.

[0176] Referring to FIGS. **6**, **8**, and **14**, the output of the light LI may gradually increase from the third output P**3** to the second output P**2**, and to the first output P**1**, and then gradually decrease to the third output P**3**. The temperature of the substrate W may drop during the transfer process. In this case, by slowly increasing the temperature of the substrate W, the rapid change in the temperature of the substrate W while light-treating the substrate W may be minimized.

[0177] FIG. **15** is a diagram illustrating a view of the substrate processing apparatus performing the cooling operation of FIG. **6**.

[0178] Referring to FIGS. **6** and **15**, in the cooling operation S**40**, the light-treated substrates W may be supported on the support shelves **840** in the cooling chamber **800**, and the cooling gas supply unit **830** may supply cooling gas CG to cool the substrate W. The temperature of the cooling gas CG may be at room temperature, or may be controlled and supplied at a lower temperature.

[0179] In the examples described above, the case where the light filter is the light source tube **655** has been described as an example, but the present invention is not limited thereto. For example, as illustrated in FIG. **16**, the light filter may be the middle plate **652**. In this case, the middle plate **652** may have a film PI attached that filters out wavelengths other than the visible light range from the light. Alternatively, the middle plate **652** may have a coating layer formed that filters out wavelengths other than the visible light range from the light.

[0180] In the examples described above, the case where the light filter is the light source tube **655** or the middle plate **652** has been described as an example, but the present invention is not limited thereto. The light filter may also refer to a film or a coating layer that is attached to the light source tube **655** or the middle plate **652**.

[0181] FIG. **17** is a diagram illustrating a view of light source tubes that may be applied to the light irradiation unit of the present invention. A user may have the light source tubes **655** that are light filters that selectively allow different ranges of wavelengths to pass through. For example, a first light source tube **655-1** may selectively allow wavelengths in the visible light range to pass through, a second light source tube **655-2** may selectively allow wavelengths in the infrared range to pass through, and a third light source tube **655-3** may selectively allow wavelengths in the ultraviolet range to pass through. The user may install any one selected from the light source tubes **655** in the light irradiation unit **650** to process the substrate W, depending on the type of organic matter remaining on the substrate W.

[0182] Similarly, as illustrated in FIG. **18**, a user may have the middle plates **652** that are light filters that selectively allow different ranges of wavelengths to pass through. For example, a first middle plate **655-1** may selectively allow wavelengths in the visible light range to pass through, a second middle plate **655-2** may selectively allow wavelengths in the infrared range to pass through, and a third middle plate **655-3** may selectively allow wavelengths in the ultraviolet range to pass through. A user may install any one selected from the middle plates **652** in the light irradiation unit **650** to process the substrate W, depending on the type of organic matter remaining on the substrate W.

[0183] In the above example, the second treatment module **30** is shown to be installed at a location adjacent to the index frame **14**. Alternatively, however, the second treatment module **30** may be disposed within the first treatment module **20**, as illustrated in FIG. **19**. Optionally, the second treatment module **30** may be stacked with the buffer unit **200**, as illustrated in FIG. **20**.

[0184] The foregoing detailed description illustrates the present invention. In addition, the above description shows and describes the exemplary embodiments of the present invention, and the present invention may be used in various other combinations, modifications, and environments. That is, changes or modifications are possible within the scope of the concept of the invention disclosed herein, the scope equivalent to the written disclosure, and/or within the scope of skill or knowledge in the art. The foregoing exemplary embodiment describes the best state for implementing the technical spirit of the present invention, and various changes required in specific application fields and uses of the present invention are possible. Accordingly, the detailed description of the invention above is not intended to limit the invention to the disclosed exemplary embodiment. In addition, the appended claims should be construed to include other exemplary embodiments as well.

1. An apparatus for processing a substrate, the apparatus comprising:

a liquid treatment chamber for liquid-treating a substrate by supplying a treatment liquid to the substrate;

a drying chamber for drying-treating the substrate treated in the liquid treatment chamber; and

a light treatment chamber for irradiating the substrate treated in the drying chamber with light to remove an organic matter residual on the substrate,

wherein the light treatment chamber includes:

a treatment housing having a treatment space in which the substrate is processed;

a support member for supporting the substrate in the treatment space;

a light source for irradiating the substrate supported on the support member with light in the form of pulses; and

a light filter for selecting a set range of wavelengths of the light generated by the light source and allowing the selected wavelengths to pass through.

2. The apparatus of claim **1**, wherein the light filter is configured to filter wavelengths, other than wavelengths of a visible light range, in the wavelengths of the light generated by the light source.

3. The apparatus of claim **2**, wherein the light filter has a tube shape surrounding the light source.

4. The apparatus of claim **3**, wherein the light filter is formed from a material including quartz, and a film that filters wavelengths other than the wavelengths of the visible light range is attached to a surface of the light filter, or a coating layer is formed on a surface of the light filter.

5. The apparatus of claim **2**, wherein the light treatment chamber includes:

a light source housing that defines a space in which the light source is placed, and

the light filter is disposed between the light source housing and the treatment housing, and

the light filter has a plate shape to compartmentalize the treatment space of the treatment housing and the space of the light source housing from each other, and a film that filters the wavelengths other than the wavelengths of the visible light range is attached to a surface of the light filter or a coating layer is formed on a surface of the light filter.

6. The apparatus of claim **2**, wherein the light filter is configured to filter wavelengths in the range of 350 to 700 nm in the wavelengths of the light generated by the light source.

7. The apparatus of claim **2**, wherein the light source is a xenon flash lamp, and generates light having wavelengths in the range of 300 to 1000 nm.

8. The apparatus of claim **2**, further comprising:

a light source controller for controlling an operation of the light source,

wherein the light source controller is configured to control at least one of an output of the light generated by the light source, a duty ratio in a unit pulse of light, and a period of the unit pulse of light.

9. The apparatus of claim **8**, wherein the light source controller controls the light source such that an output of the unit pulse of the light generated by the light source in an on state or a high state is constant during light treatment of the substrate supported on the support member.

10. The apparatus of claim **8**, wherein the light source controller controls the light source such that an output of the unit pulse of the light generated by the light source in an on state or a high state becomes gradually smaller during light treatment of the substrate supported on the support member.

11. The apparatus of claim **8**, wherein the light source controller controls the light source such that the duty ratio of the unit pulse of the light generated by the light source varies during light treatment of the substrate supported on the support member.

12. The apparatus of claim **11**, wherein the light source controller controls the light source such that the duty ratio of the unit pulse of the light generated by the light source becomes gradually smaller during light treatment of the substrate supported on the support member.

13.-**18**. (canceled)

19. An apparatus for processing a substrate, the apparatus comprising:

a liquid treatment chamber for liquid-treating a substrate by supplying an organic solvent to the substrate;

a drying chamber for drying the substrate by supplying a supercritical fluid to the substrate treated in the liquid treatment chamber; and

a light treatment chamber for irradiating the substrate treated in the drying chamber with light to remove an organic matter residual on the substrate,

wherein the light treatment chamber includes:

a treatment housing having a treatment space in which the substrate is processed;

a support member for supporting the substrate in the treatment space; and

a light irradiation unit located on an upper side of the treatment housing and for irradiating the substrate supported on the support member with light, and

the light irradiation unit includes:

a xenon flash lamp for irradiating the substrate supported on the support member with light in the form of pulses, in which the xenon flash lamp is configured to generate light having wavelengths in the range of 300 to 1000 nm;

a light source housing providing a space in which the xenon flash lamp is installed;

a light filter configured to select wavelengths in the visible light range in the wavelengths of the light generated by the xenon flash lamp and allows the selected wavelengths to pass through;

a reflective member installed on a top side of the xenon flash lamp, and for reflecting light generated by the xenon flash lamp toward the substrate;

a middle plate disposed between the light source housing and the treatment housing, and having a middle plate refrigerant flow path formed therein; and

a refrigerant supply unit for supplying the refrigerant, and

the refrigerant supply unit includes:

a refrigerant supply source for supplying a refrigerant;

a first supply line for supplying the refrigerant from the refrigerant supply source to a reflective member refrigerant flow path formed in the reflective member; and

a first delivery line for delivering the refrigerant from the reflective member refrigerant flow path to the middle plate refrigerant flow path.

20. The apparatus of claim **19**, wherein the light irradiation unit further includes a light source tube in a shape of a tube surrounding the xenon flash lamp,

a light source tube refrigerant flow path is formed within the light source tube, and

the refrigerant supply unit includes:

a second supply line for supplying the refrigerant from the refrigerant supply source to the light source tube refrigerant flow path; and

a third delivery line for delivering the refrigerant from the light source tube refrigerant flow path to a cooling plate refrigerant flow path of a cooling plate, in which the cooling plate is included in the treatment housing and located on a lower side of the support member.

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