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PROCESSING LIQUID SUPPLY SYSTEM, PROCESSING LIQUID SUPPLY METHOD, AND RECORDING MEDIUM

Abstract

A processing liquid supply system includes a processing liquid supply path, a pump, a pressure gauge and a flowmeter, and a controller. Through the processing liquid supply path, a processing liquid is supplied to a substrate processing device configured to process a substrate. The pump is provided in the processing liquid supply path. The pressure gauge and the flowmeter are provided downstream of the pump in the processing liquid supply path. The controller controls individual components. The controller detects abnormality in supply of the processing liquid based on a measurement value of the pressure gauge and a measurement value of the flowmeter.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION
[0001] This application claims the benefit of Japanese Patent Application No. 2024-017893 filed on Feb. 8, 2024, the entire disclosures of which are incorporated herein by reference.
TECHNICAL FIELD
[0002] The various aspects and embodiments described herein pertain generally to a processing liquid supply system, a processing liquid supply method, and a recording medium.
BACKGROUND
[0003] Conventionally, there is known a substrate processing apparatus configured to circulate a processing liquid through a processing tub for processing a substrate to perform various types of processes on the substrate immersed in the processing tub (see Patent Document 1). [0004] Patent Document 1: Japanese Patent Laid-open Publication No. 2021-022707
SUMMARY
[0005] In one or more embodiments of the present application, a processing liquid supply system includes a processing liquid supply path, a pump, a pressure gauge and a flowmeter, and a controller. Through the processing liquid supply path, a processing liquid is supplied to a substrate processing device configured to process a substrate. The pump is provided in the processing liquid supply path. The pressure gauge and the flowmeter are provided downstream of the pump in the processing liquid supply path. The controller controls individual components. The controller detects abnormality in supply of the processing liquid based on a measurement value of the pressure gauge and a measurement value of the flowmeter.
[0006] The foregoing summary is illustrative only and is not intended to be any way limiting. In addition to the illustrative aspects, embodiments, and features described above, further aspects, embodiments, and features will become apparent by reference to the drawings and the following detailed description.

Description

BRIEF DESCRIPTION OF THE DRAWINGS
[0007] In the detailed description that follows, embodiments are described as illustrations only since various changes and modifications will become apparent to those skilled in the art from the following detailed description. The use of the same reference numbers in different figures indicates similar or identical items.
[0008] FIG. **1** is a block diagram illustrating a configuration example of a substrate processing apparatus according to one or more embodiments of the present application;
[0009] FIG. **2** is a diagram illustrating a configuration example of a liquid processing device according to one or more embodiments of the present application;
[0010] FIG. **3** is a diagram illustrating a configuration example of a processing liquid supply system according to one or more embodiments of the present application;
[0011] FIG. **4** is a timing chart illustrating an example sequence of a startup processing performed by the substrate processing apparatus according to one or more embodiments of the present application;
[0012] FIG. **5** is a timing chart illustrating an example sequence of a detection processing

performed by the processing liquid supply system according to one or more embodiments of the present application;
[0013] FIG. **6** is a timing chart illustrating an example sequence of the detection processing performed by the processing liquid supply system according to one or more embodiments of the present application;
[0014] FIG. **7** is a diagram illustrating an example of a monitoring table for use in the detection processing performed by the processing liquid supply system according to the exemplary embodiment;
[0015] FIG. **8** is a diagram illustrating a configuration example of a processing liquid supply system according to a first modification example of one or more embodiments of the present application;
[0016] FIG. **9** is a diagram illustrating a configuration example of a processing liquid supply system according to a second modification example of one or more embodiments of the present application;
[0017] FIG. **10** is a block diagram illustrating a configuration example of a liquid processing device according to a third modification example of one or more embodiments of the present application;
[0018] FIG. **11** is a diagram illustrating a configuration example of the processing liquid supply system according to the third modification example of one or more embodiments of the present application;
[0019] FIG. **12** is a flowchart illustrating an example sequence of a control processing performed by the processing liquid supply system according to one or more embodiments of the present application; and
[0020] FIG. **13** is a flowchart illustrating an example sequence of a control processing performed by the processing liquid supply system according to one or more embodiments of the present application.

DETAILED DESCRIPTION

[0021] In the following detailed description, reference is made to the accompanying drawings, which form a part of the description. In the drawings, similar symbols typically identify similar components, unless context dictates otherwise. Furthermore, unless otherwise noted, the description of each successive drawing may reference features from one or more of the previous drawings to provide clearer context and a more substantive explanation of the current exemplary embodiment. Still, the exemplary embodiments described in the detailed description, drawings, and claims are not meant to be limiting. Other embodiments may be utilized, and other changes may be made, without departing from the spirit or scope of the subject matter presented herein. It will be readily understood that the aspects of the present disclosure, as generally described herein and illustrated in the drawings, may be arranged, substituted, combined, separated, and designed in a wide variety of different configurations, all of which are explicitly contemplated herein.
[0022] Hereinafter, one or more embodiments of the present application of a processing liquid supply system, a processing liquid supply method, and a recording medium according to the present disclosure will be described in detail with reference to the accompanying drawings. However, the present disclosure is not limited by the one or more embodiments to be described below. Also, it should be noted that the drawings are schematic and relations in sizes of individual components and ratios of the individual components may sometimes be different from actual values. Even between the drawings, there may exist parts having different dimensional relationships or different ratios.
[0023] Conventionally, there is known a substrate processing apparatus in which a processing liquid is circulated through a processing tub for processing a substrate to perform various types of processes on the substrate immersed in the processing tub. In this technique, a flow rate feedback control is performed to control an output of a pump based on a flow rate measured by a flowmeter,

for example. This makes it possible to stably supply the processing liquid to a substrate processing device such as the processing tub at a required flow rate.
[0024] Meanwhile, if bubbles are formed in a processing liquid supply path for supplying the processing liquid and if these bubbles adhere to the flowmeter, a measurement value of the flowmeter may differ from an actual flow rate. In this way, when abnormality in the supply of the processing liquid occurs in the processing liquid supply path, this abnormality cannot be detected in the aforementioned conventional technique, so there is a risk that a control such as the flow rate feedback control cannot be performed appropriately.
[0025] To overcome the aforementioned problem, there is a demand for a technique capable of detecting the supply abnormality in the processing liquid supply path.
<Configuration of Substrate Processing Apparatus>
[0026] First, a configuration of a substrate processing apparatus **1** including a processing liquid supply system **3** according to the present disclosure will be explained with reference to FIG. **1**. FIG. **1** is a block diagram illustrating a configuration example of the substrate processing apparatus **1** according to an exemplary embodiment.
[0027] As shown in FIG. **1**, the substrate processing apparatus **1** according to one or more embodiments of the present application is equipped with a liquid processing device **2**, a processing liquid supply system **3**, and a control device **4**. The liquid processing device **2** is an example of a substrate processing device.
[0028] The liquid processing device **2** is configured to process a substrate (hereinafter, also referred to as “wafer”) such as a semiconductor wafer by using a processing liquid L (see FIG. **2**).
[0029] The processing liquid L according to the exemplary embodiment contains, by way of example, a phosphoric acid (H.sub.3PO.sub.4) aqueous solution. In the present disclosure, the phosphoric acid aqueous solution is also simply referred to as “phosphoric acid”. Further, the processing liquid L according to the exemplary embodiment may also include a silicic acid compound. This silicic acid compound can be added to the phosphoric acid aqueous solution, for example, with a solution in which colloidal silicon is dispersed.
[0030] In addition, in the present disclosure, the processing liquid L is not limited to the one containing the phosphoric acid, and any of various types of processing liquids for liquid-processing the wafer W may be employed.
[0031] The processing liquid supply system **3** is configured to supply the above-described processing liquid L to the liquid processing device **2**. A configuration example of the processing liquid supply system **3** will be described later.
[0032] The control device **4** controls the liquid processing device **2** and the processing liquid supply system **3**. The control device **4** is, for example, a computer, and includes a controller **5** and a storage **6**. The storage **6** stores therein programs for controlling various types of processes performed in the substrate processing apparatus **1**. The controller **5** controls operations of the liquid processing device **2** and the processing liquid supply system **3** by reading and executing the programs stored in the storage **6**. The functionality of the elements disclosed herein may be implemented using circuitry or processing circuitry which includes general purpose processors, special purpose processors, integrated circuits, ASICs (“Application Specific Integrated Circuits”), FPGAs (“Field-Programmable Gate Arrays”), conventional circuitry and/or combinations thereof which are programmed, using one or more programs stored in one or more memories, or otherwise configured to perform the disclosed functionality. Processors and controllers are considered processing circuitry or circuitry as they include transistors and other circuitry therein. In the disclosure, the circuitry, units, or means are hardware that carry out or are programmed to perform the recited functionality. The hardware may be any hardware disclosed herein which is programmed or configured to carry out the recited functionality. There is a memory that stores a computer program which includes computer instructions. These computer instructions provide the logic and routines that enable the hardware (e.g., processing circuitry or circuitry) to perform the

method disclosed herein. This computer program can be implemented in known formats as a computer-readable storage medium, a computer program product, a memory device, a record medium such as a CD-ROM or DVD, and/or the memory of a FPGA or ASIC.

[0033] Further, these programs may be recorded on a computer-readable recording medium and installed from the recording medium into the storage **6** of the control device **4**. The computer-readable recording medium may be, by way of non-limiting example, a hard disk (HD), a flexible disk (FD), a compact disk (CD), a magnet optical disk (MO), a memory card, or the like.

[0034] The substrate processing apparatus **1** may be equipped with a plurality of liquid processing devices **2**. In this case, the substrate processing apparatus **1** may include a plurality of processing liquid supply systems **3** respectively corresponding to the plurality of liquid processing devices **2**, or may include one processing liquid supply system **3** corresponding to all the plurality of liquid processing devices **2**.

<Configuration of Liquid Processing Device>

[0035] Now, a configuration example of the liquid processing device **2** will be described with reference to FIG. **2**. FIG. **2** is a diagram illustrating an example of the configuration of the liquid processing device **2** according to one or more embodiments of the present application.

[0036] The liquid processing device **2** shown in FIG. **2** is a batch type processing device configured to process a multiple number of wafers W (only one is shown in FIG. **2**) all at once. As depicted in FIG. **2**, the liquid processing device **2** is equipped with a processing tub **21**, a holder **22**, and a plurality of (here, four) dischargers **23**. Here, the number of the dischargers **23** included in the liquid processing device **2** is not limited to four.

[0037] The processing tub **21** includes an inner tub **21***a* and an outer tub **21***b*. The inner tub **21***a* is a box-shaped tub with an open top, and stores the processing liquid L therein. A lot composed of a plurality of wafers W is immersed in the inner tub **21***a*. The outer tub **21***b* is disposed around the inner tub **21***a*. The outer tub **21***b* also has an open top. The processing liquid L that has overflown from the inner tub **21***a* is introduced into the outer tub **21***b*.

[0038] The holder **22** is configured to hold the multiple number of wafers W forming the lot in a vertical posture. The holder **22** has an elevating mechanism (not shown) configured to move the wafers W held thereby up and down, and serves to lower the lot from above the inner tub **21***a* in the processing tub **21** to immerse it in the inner tub **21***a*, or raise the lot immersed in the inner tub **21***a* to take it out from the processing tub **21**.

[0039] The plurality of dischargers **23** are disposed inside the inner tub **21***a*, specifically, in the vicinity of a bottom of the inner tub **21***a*. The dischargers **23** are connected to the processing liquid supply system **3**, and discharge the processing liquid L supplied from the processing liquid supply system **3** into the inner tub **21***a*.

[0040] The liquid processing device **2** holds the lot with the holder **22**, and immerses the lot held thereby in the processing liquid L stored in the inner tub **21***a*. As a result, the multiple number of wafers W are processed by the processing liquid L.

[0041] For example, in one or more embodiments of the present application, among a silicon nitride film and a silicon oxide film formed on the wafer W, the silicon nitride film is selectively etched by the phosphoric acid aqueous solution, which is the processing liquid L.

<Configuration of Processing Liquid Supply System>

[0042] Now, a configuration example of the processing liquid supply system **3** will be described with reference to FIG. **3**. FIG. **3** is a diagram illustrating a configuration example of the processing liquid supply system **3** according to one or more embodiments of the present application.

[0043] As depicted in FIG. **3**, the processing liquid supply system **3** includes a processing liquid supply **31** and a circulation path **32**. The circulation path **32** is an example of a processing liquid supply path. The processing liquid supply **31** supplies the processing liquid L to the processing tub **21**. The processing liquid supply **31** supplies unused processing liquid L to the inner tub **21***a* of the processing tub **21**, for example.

[0044] The processing liquid supply **31** has a source **31***a*, a supply path **31***b*, and a flow rate controller **31***c*. The source **31***a* is, for example, a tank that stores the processing liquid L therein. The supply path **31***b* connects the source **31***a* to the inner tub **21***a*, allowing the processing liquid L to be supplied from the source **31***a* to the inner tub **21***a*. Also, the supply path **31***b* may be connected to the outer tub **21***b*.
[0045] The flow rate controller **31***c* is provided in the supply path **31***b*, and serves to adjust the amount of the processing liquid L supplied to the processing tub **21**. The flow rate controller **31***c* is composed of, by way of example, an opening/closing valve, a flow control valve, a flowmeter, and so forth.
[0046] The circulation path **32** is connected to the liquid processing device **2** to supply the processing liquid L to the liquid processing device **2**. The circulation path **32** is a circulation line through which the processing liquid L flowing out from the processing tub **21** is returned back into the processing tub **21**.
[0047] Specifically, one end of the circulation path **32** is connected to multiple positions (two positions in FIG. **3**) at a bottom of the outer tub **21***b*, and the other end of the circulation path **32** is connected to the plurality of dischargers **23** located inside the inner tub **21***a*. In the processing liquid supply system **3**, the processing liquid L sent from the outer tub **21***b* into the circulation path **32** passes through the circulation path **32** and is then supplied from the dischargers **23** into the inner tub **21***a*.
[0048] Furthermore, the processing liquid L supplied from the dischargers **23** into the inner tub **21***a* overflows from the inner tub **21***a* into the outer tub **21***b*. In this way, the circulation path **32** allows the processing liquid L to be circulated between the inner tub **21***a* and the outer tub **21***b*.
[0049] The circulation path **32** is provided with a pump **33**, a pressure gauge **34**, a check valve **35**, a heater **36**, a filter **37**, a branching portion **38**, and a flowmeter **39** in this order from the upstream side with respect to the processing tub **21**.
[0050] The pump **33** forms a circulating flow of the processing liquid L that comes out from the processing tub **21**, passes through the circulation path **32**, and returns back into the processing tub **21**. The pump **33** is, by way of non-limiting example, a magnetic levitation pump configured to force-feed the processing liquid L as a rotator thereof is rotated in the processing liquid L while being magnetically levitated. However, the pump **33** of the present disclosure is not limited to the magnetic levitation pump, and may be, by way of example, a diaphragm pump or the like.
[0051] Meanwhile, since the magnetic levitation pump, which has higher liquid feeding capacity than other types of pumps, is used for the pump **33**, the feed flow rate of the processing liquid L returned from the circulation path **32** into the processing tub **21** can be increased.
[0052] The pressure gauge **34** measures the pressure of the processing liquid L flowing through the circulation path **32**. A measurement value of the pressure of the processing liquid L measured by the pressure gauge **34** is outputted to the controller **5** (see FIG. **1**). The check valve **35** suppresses a backflow of the processing liquid L flowing through the circulation path **32**. The check valve **35** is, by way of non-limiting example, an air-operated valve.
[0053] The heater **36** heats the processing liquid L flowing through the circulation path **32**. In this exemplary embodiment, by heating the processing liquid L with this heater **36**, the processing liquid L stored in the processing tub **21** is heated up to a processing temperature (for example, about 160° C. to 170° C.) required for processing the wafer W.
[0054] The filter **37** is configured to remove contaminants such as particles contained in the processing liquid L flowing through the circulation path **32**. The filter **37** may include a plurality of filter modules arranged in parallel.
[0055] The number of the filter modules belonging to the single filter **37** may be decided in consideration of filtration ability required for the filter **37**, a pressure drop allowed in the filter **37**, and so forth. In the present disclosure, the filter **37** is composed of two filter modules arranged in parallel, as illustrated in FIG. **3**.

[0056] A branch path **41** leading to the outer tub **21***b* of the processing tub **21** is branched off from the branching portion **38**. The flowmeter **39** measures the flow rate of the processing liquid L flowing through the circulation path **32**. A measurement value of the flow rate of the processing liquid L measured by the flowmeter **39** is outputted to the controller **5**.
[0057] The branch path **41** is a flow path for sampling the concentration of the processing liquid L flowing through the circulation path **32**. A flowmeter **42**, a concentration meter **43**, and a valve **44** are provided in this branch path **41** in this order from the upstream side with respect to the branching portion **38**.
[0058] The flowmeter **42** measures the flow rate of the processing liquid L flowing through the branch path **41**. A measurement value of the flow rate of the processing liquid L measured by the flowmeter **42** is outputted to the controller **5**.
[0059] The concentration meter **43** measures the concentration of the processing liquid L flowing through the branch path **41**, which reflects the concentration of the processing liquid Lflowing through the circulation path **32**. The concentration meter **43** measures, for example, a phosphoric acid concentration of the processing liquid L flowing through the branch path **41**. A measurement value of the concentration of the processing liquid L measured by the concentration meter **43** is outputted to the controller **5**. The valve **44** controls whether or not the processing liquid L is to be supplied from the branching portion **38** to the outer tub **21***b*.
[0060] The processing liquid supply system **3** is also equipped with a thermometer **45**. The thermometer **45** measures the temperature of the processing liquid L flowing through the circulation path **32** by measuring the temperature of the processing liquid L stored in the processing tub **21**. The thermometer **45** measures the temperature of the processing liquid L stored in the inner tub **21***a*, for example. A measurement value of the temperature of the processing liquid L measured by the thermometer **45** is outputted to the controller **5**.
[0061] Furthermore, the thermometer **45** of the present disclosure is not limited to measuring the temperature of the processing liquid L stored in the inner tub **21***a*, but may be configured to measure the temperature of the processing liquid L stored in the outer tub **21***b* or to measure the temperature of the processing liquid L flowing through the circulation path **32**.
<Startup Process>
[0062] Now, an outline of a startup processing of the substrate processing apparatus **1** according to one or more embodiments of the present application will be described with reference to FIG. **4**. FIG. **4** is a timing chart showing an example sequence of the startup processing performed by the substrate processing apparatus **1** according to the embodiment.
[0063] First, the controller **5** (see FIG. **1**) performs a draining processing of draining all the processing liquid L used (see FIG. **3**) from the inner tub **21***a* (see FIG. **3**) and the outer tub **21***b* (see FIG. **3**) of the processing tub **21** (see FIG. **3**) from time T**01**.
[0064] Next, from time T**02** when the draining processing is completed, the controller **5** performs a storage processing of replenishing the inner tub **21***a* and the outer tub **21***b* of the processing tub **21** with the processing liquid L unused. Specifically, the controller **5** first supplies the processing liquid L from the processing liquid supply **31** (see FIG. **3**) to the inner tub **21***a*, filling the inner tub **21***a* with the processing liquid L.
[0065] Next, the controller **5** further supplies the processing liquid L from the processing liquid supply **31** into the inner tub **21***a*, thus allowing the processing liquid L overflowing from the inner tub **21***a* to be supplied into the outer tub **21***b*. Then, at time T**04** when the liquid level of the processing liquid L supplied to the outer tub **21***b* reaches a predetermined second height, the controller **5** ends the storage processing.
[0066] The controller **5** performs a circulation processing of circulating the processing liquid L through the circulation path **32** (see FIG. **3**) from time T**03** when the liquid level of the processing liquid L supplied into the outer tub **21***b* reaches a preset first height, which is lower than the second height. During this circulation processing, from time T**05** when the processing liquid L meets a

condition to be described below, the controller **5** performs a temperature control processing of adjusting the temperature of the processing liquid L to a preset processing temperature.

<Details of Detection Processing>

[0067] Now, details of a detection processing of detecting abnormality in the supply of the processing liquid L in the processing liquid supply system **3** according to one or more embodiments of the present application will be described with reference to FIG. **5** to FIG. **7**. FIG. **5** is a timing chart illustrating an example sequence of the detection processing performed by the processing liquid supply system **3** according to one or more embodiments of the present application.

[0068] As shown in FIG. **5**, the controller **5** (see FIG. **1**) operates the pump **33** (see FIG. **3**) from the aforementioned time T**03** to allow the processing liquid L (see FIG. **3**) to flow through the circulation path **32** (see FIG. **3**), thereby performing a circulation processing in which the processing liquid L is circulated through the circulation path **32**.

[0069] In addition, when a magnetic levitation pump is used for the pump **33**, there are two types of operation modes for the pump **33**: a flow rate feedback control (referred to as “flow rate FB control” in the accompanying drawings) and a rotation speed control.

[0070] In flow rate feedback control, the rotation speed of the rotator inside the pump **33** is automatically controlled so that a flow rate measurement value of the processing liquid L measured by the flowmeter **39** (see FIG. **3**) reaches a designated flow rate.

[0071] By way of example, in the flow rate feedback control, if the flow rate measurement value of the processing liquid L is lower than the designated flow rate, the pump **33** increases the rotation speed of the rotator. On the other hand, in the flow rate feedback control, if the flow rate measurement value of the processing liquid L is higher than the designated flow rate, the pump **33** reduces the rotation speed of the rotator.

[0072] In the rotation speed control, the rotation speed of the rotator of the pump **33** is controlled to a specified rotation speed.

[0073] In the circulation processing according to one or more embodiments of the present application, the controller **5** operates the pump **33** with the flow rate feedback control. Furthermore, in this circulation processing, the controller **5** operates the pump **33**, while setting the flow rate of the processing liquid L in the circulation path **32** to a predetermined flow rate. As a result, the measurement value of the flowmeter **39** gradually rises from zero, as shown in FIG. **5**.

[0074] Next, in the present exemplary embodiment, from the time T**05** after the start of the circulation processing, the controller **5** operates the heater **36** (see FIG. **3**) to perform a temperature control processing for the processing liquid L. Here, the time T**05** is a time upon the lapse of a predetermined time period from time T**11** at which the measurement value of the flowmeter **39** reaches a minimum circulation flow rate F.sub.L.

[0075] In this way, by allowing a margin of a certain period of time before operating the heater **36** instead of operating the heater **36** immediately after the minimum circulation flow rate F.sub.Lis reached, it is possible to operate the heater **36** after ensuring a sufficient circulation flow rate in the circulation path **32**.

[0076] Therefore, according to one or more embodiments of the present application, it is possible to suppress problems that might be caused by operating the heater **36** in a situation where the flow rate in the circulation path **32** is not enough.

[0077] In the present exemplary embodiment, from time T**12** later than the time T**05**, there occurs a phenomenon in which the measurement value obtained by the flowmeter **39** does not fluctuate but remains constant (hereinafter, also referred to as “flowmeter hold phenomenon”). This flowmeter hold phenomenon takes place as a result of bubbles generated in the processing liquid L adhering to the flowmeter **39**, for example.

[0078] In the example of FIG. **5**, an actual flow rate of the processing liquid L indicated by a dashed line gradually decreases from the time T**12**. Since, however, there is no change in the measurement value of the flowmeter **39**, the pump **33** performs the flow rate feedback control so as not to change the rotation speed of the rotator.

[0079] Since the rotation speed of the rotator of the pump **33** does not fluctuate, a measurement value of the pressure gauge **34** (see FIG. **3**) provided in the circulation path **32** also gradually decreases from the time T**12**.

[0080] Here, in one or more embodiments of the present application, the controller **5** detects the abnormal supply of the processing liquid L based on the measurement value of the pressure gauge **34** and the measurement value of the flowmeter **39**. By way of example, in the example of FIG. **5**, when there is no change in the measurement value of the flowmeter **39** and the measurement value of the pressure gauge **34** becomes equal to or lower than a predetermined lower limit pressure P.sub.L (time T**13** in the example of FIG. **5**), the controller **5** detects the abnormality in the supply of the processing liquid L.

[0081] This makes it possible to detect abnormality in the supply of the processing liquid L even when the flowmeter **39** is not outputting an appropriate measurement value due to bubbles adhering thereto, or the like.

[0082] Furthermore, in one or more embodiments of the present application, the circulation processing and the temperature control processing are continued even after the time T**13** when the abnormality in the supply of the processing liquid L is detected. Accordingly, if the flowmeter **39** resumes outputting an appropriate measurement value after the time T**13** due to removal of the bubbles or the like adhering thereto, the circulation processing and the temperature control processing can be carried on.

[0083] In the present exemplary embodiment, however, even at time T**14** upon the lapse of a preset time period D**1** from the time T**13**, the measurement value of the flowmeter **39** does not change, and the measurement value of the pressure gauge **34** is still found to be below the lower limit pressure P.sub.L.

[0084] In this case, the controller **5** makes a determination that the flowmeter **39** is unlikely to resume the output of an appropriate measurement value, so the controller **5** stops the operations of the pump **33** and the heater **36**, thereby stopping the circulation processing and the temperature control processing. This makes it possible to suppress damage to the processing liquid supply system **3** and the liquid processing device **2** due to the abnormality in the supply of the processing liquid L.

[0085] FIG. **6** is a timing chart showing an example sequence of the detection processing performed by the processing liquid supply system **3** according to one or more embodiments of the present application. FIG. **6** shows an example where the startup processing of the substrate processing apparatus **1** (see FIG. **1**) is completed and the processing liquid L (see FIG. **3**) is flowing through the circulation path **32** (see FIG. **3**) at a processing flow rate F.sub.s for processing the wafer W (see FIG. **2**).

[0086] In this case, the controller **5** (see FIG. **1**) operates the pump **33** (see FIG. **3**) by setting the operation mode of the pump **33** to be the flow rate feedback control, as illustrated in FIG. **6**. Furthermore, in this flow rate feedback control, the flow rate of the processing liquid L in the circulation path **32** is set to the processing flow rate F.sub.s. This allows the controller **5** to stably supply the processing liquid L to the liquid processing device **2** at the processing flow rate F.sub.s.

[0087] In the example of FIG. **6**, the flowmeter hold phenomenon occurs at time T**21**. In this case, the controller **5** maintains the control over the pump **33** in the flow rate feedback control mode from this time T**21** until a predetermined time period D**2** (e.g., about 5 seconds) elapses.

[0088] In this way, by maintaining the flow rate feedback control during the time period D**2**, when the flowmeter **39** resumes outputting an appropriate measurement value after the time T**21** due to elimination of the bubbles or the like, the feeding of the processing liquid L from the processing liquid supply system **3** can be continued.

[0089] In the example of FIG. **6**, since the flowmeter hold phenomenon has been resolved at time T**22** before the lapse of the predetermined time period D**2** from the time T**21**, the controller **5** is

continuing to operate the pump **33** even after the time T**22**, under the flow rate feedback control in which the set flow rate is set to the processing flow rate F.sub.s.
[0090] In the example of FIG. **6**, the flowmeter hold phenomenon occurs again at time T**23** later than the time T**22**. In this case, the same as described above, the controller **5** maintains the control over the pump **33** in the flow rate feedback control mode from this time T**23** until the predetermined time period D**2** passes by.
[0091] Also, in the example of FIG. **6**, the flowmeter hold phenomenon lasts even at time T**24** upon the lapse of the predetermined time period D**2** from the time T**23**. In this case, the controller **5** detects abnormality in the supply of the processing liquid L.
[0092] Thus, even when the flowmeter **39** is not outputting an appropriate measurement value due to bubbles adhering thereto or the like, the abnormality in the supply of the processing liquid L may be detected.
[0093] Then, as depicted in FIG. **6**, at the time T**24** when the abnormality in the supply of the processing liquid L is detected, the controller **5** switches the operation mode of the pump **33** from the flow rate feedback control to the rotation speed control.
[0094] In this case, the controller **5** calculates a rotation speed R**1** at which the pump **33** is capable of feeding the processing liquid L at the processing flow rate F.sub.s from the following expression (1), and operates the pump **33** at this rotation speed R**1**.

$R1(\text{rpm})=F.\text{sub}.s(\text{L/min})\times B \qquad (1)$

[0095] The parameter B included in the expression (1) is a rotational speed (rpm/L) of the pump **33** for feeding **1**L of the processing liquid L per minute, and this value is determined individually based on the liquid feeding capacity of the pump **33**.
[0096] In this way, by switching the operation mode of the pump **33** to the rotation speed control, it is possible to circulate the processing liquid L at a flow rate close to the processing flow rate F.sub.s even in the event of the flowmeter hold phenomenon in which the flow rate feedback control cannot be performed appropriately.
[0097] Therefore, according to the present exemplary embodiment, even if the flowmeter **39** does not output a proper measurement value due to, for example, adhesion of bubbles thereto, the processing liquid L can still be fed.
[0098] Further, in the example of FIG. **6**, the flowmeter hold phenomenon is resolved at time T**25**, which is later than the time T**24**. In this case, the controller **5** switches the operation mode of the pump **33** from the rotation speed control to the flow rate feedback control at the time T**25** when the flowmeter hold phenomenon is resolved. In this flow rate feedback control, the flow rate of the processing liquid L in the circulation path **32** is set to the processing flow rate F.sub.s.
[0099] Accordingly, when the flowmeter **39** is operating normally, the flow rate of the processing liquid L in the circulation path **32** can be accurately maintained at the processing flow rate F.sub.s.
[0100] FIG. **7** illustrates an example of a monitoring table used in the detection processing performed by the processing liquid supply system **3** according to one or more embodiments of the present application. In one or more embodiments of the present application, the storage **6** (see FIG. **1**) stores the monitoring table of FIG. **7** in which a pressure threshold according to the temperature of the processing liquid L is set.
[0101] The controller **5** (see FIG. **1**) detects abnormality in the supply of the processing liquid L when a measurement value of the pressure gauge **34** exceeds the pressure threshold according to the temperature of the processing liquid L set in the monitoring table stored in the storage **6**.
[0102] By way of example, in the example of FIG. **7**, when the temperature of the processing liquid L is less than a temperature A.sub.1, the pressure threshold is P.sub.7. Then, when the measurement value of the thermometer **45** becomes less than the temperature A.sub.1 and the measurement value of the pressure gauge **34** exceeds a pressure P.sub.7, the controller **5** detects abnormality in the supply of the processing liquid L and immediately stops the operations of the pump **33** and the

heater **36**.

[0103] This makes it possible to suppress damage to the processing liquid supply system **3** and the liquid processing device **2** that might be caused by the abnormality in the supply of the processing liquid L.

[0104] Further, in the example of FIG. **7**, when the temperature of the processing liquid L is equal to or higher than the temperature A.sub.1 and less than a temperature A.sub.2, the pressure threshold is a pressure P.sub.6. Then, when the measurement value of the thermometer **45** becomes equal to or higher than the temperature A.sub.1 and less than the temperature A.sub.2, and the measurement value of the pressure gauge **34** exceeds the pressure P.sub.6, the controller **5** detects abnormality in the supply of the processing liquid L and immediately stops the operations of the pump **33** and the heater **36**.

[0105] This makes it possible to suppress damage to the processing liquid supply system **3** and the liquid processing device **2** that might be caused by the abnormality in the supply of the processing liquid L.

[0106] Also, in the example of FIG. **7**, when the temperature of the processing liquid L is equal to or higher than the temperature A.sub.2 and less than a temperature A.sub.3, the pressure threshold is a pressure P.sub.5. Then, when the measurement value of the thermometer **45** becomes equal to or higher than the temperature A.sub.2 and less than the temperature A.sub.3, and the measurement value of the pressure gauge **34** exceeds the pressure P.sub.5, the controller **5** detects abnormality in the supply of the processing liquid L and immediately stops the operations of the pump **33** and the heater **36**.

[0107] This makes it possible to suppress damage to the processing liquid supply system **3** and the liquid processing device **2** that might be caused by the abnormality in the supply of the processing liquid L.

[0108] Furthermore, in the example of FIG. **7**, when the temperature of the processing liquid L is equal to or higher than the temperature A.sub.3 and less than a temperature A.sub.4, the pressure threshold is a pressure P.sub.4. Then, when the measurement value of the thermometer **45** becomes equal to or higher than the temperature A.sub.3 and less than the temperature A.sub.4, and the measurement value of the pressure gauge **34** exceeds a pressure P.sub.4, the controller **5** detects abnormality in the supply of the processing liquid L and immediately stops the operations of the pump **33** and the heater **36**.

[0109] This makes it possible to suppress damage to the processing liquid supply system **3** and the liquid processing device **2** that might be caused by the abnormality in the supply of the processing liquid L.

[0110] Also, in the example of FIG. **7**, when the temperature of the processing liquid L is equal to or higher than the temperature A.sub.4 and less than a temperature A.sub.5, the pressure threshold is a pressure P.sub.3. Then, when the measurement value of the thermometer **45** becomes equal to or higher than the temperature A.sub.4 and less than the temperature A.sub.5, and the measurement value of the pressure gauge **34** exceeds the pressure P.sub.3, the controller **5** detects abnormality in the supply of the processing liquid L and immediately stops the operations of the pump **33** and the heater **36**.

[0111] This makes it possible to suppress damage to the processing liquid supply system **3** and the liquid processing device **2** that might be caused by the abnormality in the supply of the processing liquid L.

[0112] In the example of FIG. **7**, when the temperature of the processing liquid L is equal to or higher than the temperature A.sub.5 and less than a temperature A.sub.6, the pressure threshold is a pressure P**2**. Then, when the measurement value of the thermometer **45** becomes equal to or higher than the temperature A.sub.5 and less than the temperature A.sub.6, and the measurement value of the pressure gauge **34** exceeds the pressure P.sub.2, the controller **5** detects abnormality in the supply of the processing liquid L and immediately stops the operations of the pump **33** and the heater **36**.

[0113] This makes it possible to suppress damage to the processing liquid supply system **3** and the liquid processing device **2** that might be caused by the abnormality in the supply of the processing liquid L.

[0114] Furthermore, in the example of FIG. **7**, when the temperature of the processing liquid L is equal to or higher than the temperature A.sub.6, the pressure threshold is a pressure P.sub.1. Then, when the measurement value of the thermometer **45** becomes equal to or higher than the temperature A.sub.6 and the measurement value of the pressure gauge **34** exceeds the pressure P.sub.1, the controller **5** detects abnormality in the supply of the processing liquid L and immediately stops the operations of the pump **33** and the heater **36**.

[0115] This makes it possible to suppress damage to the processing liquid supply system **3** and the liquid processing device **2** that might be caused by the abnormality in the supply of the processing liquid L.

[0116] In addition, in the monitoring table according to one or more embodiments of the present application, the pressure threshold according to the temperature of the processing liquid L may gradually decrease as the temperature of the processing liquid L increases. With such a rise of the temperature of the processing liquid L, the pressure resistant capacity of the circulation path **32** gradually decreases. However, by setting the monitoring table as described above, it is possible to suppress damage to the processing liquid supply system **3** and the liquid processing device **2** in any temperature range.

[0117] Moreover, although FIG. **7** illustrates the example where the pressure threshold changes stepwise in the range of the temperature A.sub.1 to the temperature A.sub.6, the present disclosure is not limited thereto. The pressure threshold may vary linearly, or in a curved shape such as a quadratic curve.

Various Modification Examples

[0118] Subsequently, the processing liquid supply system **3** according to various modification examples of one or more embodiments of the present application will be explained with reference to FIG. **8** to FIG. **11**. FIG. **8** illustrates a configuration example of the processing liquid supply system **3** according to a first modification example.

[0119] In the first modification example shown in FIG. **8**, the configuration of the circulation path **32** differs from that of the above-described exemplary embodiment. Specifically, in this first modification example, multiple circulation paths **32** (two in the example of FIG. **8**) are provided for the single processing tub **21**. With this configuration, it is possible to increase the feed flow rate of the processing liquid L returned back into the processing tub **21** from the circulation path **32**, as compared to the case where only one circulation path **32** is provided for the single processing tub **21**.

[0120] The circulation path **32** according to the first modification example includes circulation paths **32**A and **32**B. The circulation paths **32**A and **32**B are an example of a processing liquid supply path. Each of the circulation paths **32**A and **32**B is connected to the liquid processing device **2** to supply the processing liquid L to the liquid processing device **2**. Each of the circulation paths **32**A and **32**B is a circulation line through which the processing liquid L flows out from the processing tub **21** and back into the processing tub **21**.

[0121] To elaborate, one end of each of the circulation paths **32**A and **32**B is connected to the bottom of the outer tub **21***b*, and the other end of each of the circulation paths **32**A and **32**B is connected to the plurality of dischargers **23** located inside the inner tub **21***a*.

[0122] In the processing liquid supply system **3**, the processing liquid L sent from the outer tub **21***b* to the circulation paths **32**A and **32**B passes through the circulation paths **32**A and **32**B and is then supplied into the inner tub **21***a* from the dischargers **23**.

[0123] Furthermore, the processing liquid L supplied from the dischargers **23** to the inner tub **21***a* overflows from the inner tub **21***a* into the outer tub **21***b*. In this way, the circulation paths **32**A and

32B circulate the processing liquid L between the inner tub **21***a* and the outer tub **21***b*.

[0124] The circulation path **32**A is provided with a pump **33**A, a pressure gauge **34**A, a check valve **35**A, a heater **36**A, a filter **37**A, and a flowmeter **39**A in this order from the upstream side with respect to the processing tub **21**.

[0125] The pump **33**A forms a circulation flow of the processing liquid L that comes out from the processing tub **21**, passes through the circulation path **32**A, and then returns back into the processing tub **21**. The pump **33**A is, for example, a magnetic levitation pump. However, it should be noted that the pump **33**A of the present disclosure is not limited to the magnetic levitation pump, and may be a diaphragm pump, or the like.

[0126] The pressure gauge **34**A measures the pressure of the processing liquid L flowing through the circulation path **32**A. A measurement value of the pressure of the processing liquid L measured by the pressure gauge **34**A is outputted to the controller **5** (see FIG. **1**). The check valve **35**A suppresses a backflow of the processing liquid L flowing through the circulation path **32**A. The check valve **35**A is, by way of non-limiting example, an air-operated valve.

[0127] The heater **36**A heats the processing liquid L flowing through the circulation path **32**A. In the first modification example, by heating the processing liquid L with the heater **36**A, the processing liquid L stored in the processing tub **21** is heated up to a processing temperature required for processing the wafer W.

[0128] The filter **37**A removes contaminants such as particles contained in the processing liquid L flowing through the circulation path **32**A. The filter **37**A may include multiple filter modules arranged in parallel.

[0129] The flowmeter **39**A measures the flow rate of the processing liquid L flowing through the circulation path **32**A. A measurement value of the flow rate of the processing liquid L measured by the flowmeter **39**A is outputted to the controller **5**.

[0130] The circulation path **32**B is provided with a pump **33**B, a pressure gauge **34**B, a check valve **35**B, a heater **36**B, a filter **37**B, the branching portion **38**, and a flowmeter **39**B in this order from the upstream side with respect to the processing tub **21**.

[0131] The pump **33**B forms a circulation flow of the processing liquid L that flows out from the processing tub **21**, passes through the circulation path **32**B, and then returns back into the processing tub **21**. The pump **33**B is, for example, a magnetic levitation pump configured to force-feed the processing liquid L as a rotator thereof is rotated in the processing liquid L while being magnetically levitated. However, the pump **33**B of the present disclosure is not limited to the magnetic levitation pump, and may be a diaphragm pump or the like.

[0132] The pressure gauge **34**B measures the pressure of the processing liquid L flowing through the circulation path **32**B. A measurement value of the pressure of the processing liquid L measured by the pressure gauge **34**B is outputted to the controller **5**. The check valve **35**B suppresses a backflow of the processing liquid L flowing through the circulation path **32**B. The check valve **35**B is, by way of non-limiting example, an air-operated valve.

[0133] The heater **36**B heats the processing liquid L flowing through the circulation path **32**B. In the first modification example, by heating the processing liquid L with this heater **36**B, the processing liquid L stored in the processing tub **21** is heated up to a processing temperature required for processing the wafer W.

[0134] The filter **37**B removes contaminants such as particles contained in the processing liquid L flowing through the circulation path **32**B. The filter **37**B may include multiple filter modules arranged in parallel.

[0135] The branch path **41** that leads to the outer tub **21***b* of the processing tub **21** is branched off from the branching portion **38**. The flowmeter **39**B measures the flow rate of the processing liquid L flowing through the circulation path **32**B. A measurement value of the flow rate of the processing liquid L measured by the flowmeter **39**B is outputted to the controller **5**.

[0136] The branch path **41** is a flow path for sampling the concentration of the processing liquid L

flowing through the circulation path **32**B. This branch path **41** is provided with the flowmeter **42**, the concentration meter **43**, and the valve **44** in this order from the upstream side with respect to the branching portion **38**.
[0137] The flowmeter **42** measures the flow rate of the processing liquid L flowing through the branch path **41**. A measurement value of the flow rate of the processing liquid L measured by the flowmeter **42** is outputted to the controller **5**.
[0138] The concentration meter **43** measures the concentration of the processing liquid L flowing through the branch path **41** to measure the concentration of the processing liquid L flowing through the circulation path **32**. The concentration meter **43** measures, for example, a phosphoric acid concentration of the processing liquid L flowing through the branch path **41**. A measurement value of the concentration of the processing liquid L measured by the concentration meter **43** is outputted to the controller **5**. The valve **44** controls whether or not the processing liquid L is to be supplied from the branching portion **38** to the outer tub **21***b*.
[0139] In the processing liquid supply system **3** of the first modification example described so far, by performing the same detection processing as in the above-described exemplary embodiment, abnormality in the supply of the processing liquid L in the circulation paths **32**A and **32**B can be detected.
[0140] In the example of FIG. **8** described so far, the circulation path **32** includes the two circulation paths **32**A and **32**B. However, the present disclosure is not limited thereto, and the circulation path **32** may include three or more circulation paths.
[0141] FIG. **9** illustrates a configuration example of the processing liquid supply system **3** according to a second modification example. The second modification example shown in FIG. **9** is different from one or more embodiments of the present application and the first modification example described above in the configuration of the circulation path **32**.
[0142] Specifically, in this second modification example, the single circulation path **32** is branched at a branching portion **50** thereof into multiple (two in the shown example) branch circulation paths **32***a* and **32***b*. The branch circulation paths **32***a* and **32***b* are an example of a processing liquid supply path.
[0143] With this configuration, the feed flow rate of the processing liquid L returned from the circulation path **32** back into the processing tub **21** can be increased, as compared to the case where the single circulation path **32** is provided from the uppermost stream to the downmost stream for the single processing tub **21**.
[0144] The circulation path **32** is provided with the pump **33**, the pressure gauge **34**, the check valve **35**, and the branching portion **50** in this order from the upstream side with respect to the processing tub **21**. Also, the circulation path **32** is branched into the branch circulation paths **32***a* and **32***b* at the branching portion **50**.
[0145] The pump **33** forms a circulation flow of the processing liquid L that flows out from the processing tub **21**, passes through the circulation path **32** and the branch circulation paths **32***a* and **32***b*, and returns back into the processing tub **21**. The pump **33** is, by way of non-limiting example, a magnetic levitation pump. However, the pump **33** of the present disclosure is not limited to the magnetic levitation pump, and may be a diaphragm pump or the like.
[0146] The pressure gauge **34** measures the pressure of the processing liquid L flowing through the circulation path **32**. A measurement value of the pressure of the processing liquid L measured by the pressure gauge **34** is outputted to the controller **5** (see FIG. **1**). The check valve **35** suppresses a backflow of the processing liquid L flowing through the circulation path **32**. The check valve **35** is, for example, an air-operated valve.
[0147] In this way, by disposing the pump **33** upstream of the branching portion **50**, the processing liquid L can be sent to the multiple branch circulation paths **32***a* and **32***b* without needing to increase the number of the pump **33**. Therefore, according to the second modification example, the manufacturing cost of the processing liquid supply system **3** can be reduced.

[0148] The branch circulation path **32***a* is provided with a heater **36**A, a filter **37**A, and a flowmeter **39**A in this order from the upstream side with respect to the branching portion **50**.
[0149] The heater **36**A heats the processing liquid L flowing through the branch circulation path **32***a*. In the second modification example, by heating the processing liquid L with this heater **36**A, the processing liquid L stored in the processing tub **21** is heated up to a processing temperature required for processing the wafer W.
[0150] The filter **37**A removes contaminants such as particles contained in the processing liquid L flowing through the branch circulation path **32***a*. The filter **37**A may include multiple filter modules arranged in parallel.
[0151] The flowmeter **39**A measures the flow rate of the processing liquid L flowing through the branch circulation path **32***a*. A measurement value of the flow rate of the processing liquid L measured by the flowmeter **39**A is outputted to the controller **5**.
[0152] The branch circulation path **32***b* is provided with a heater **36**B, a filter **37**B, a branching portion **38**, and a flowmeter **39**B in this order from the upstream side with respect to the branching portion **50**.
[0153] The heater **36**B heats the processing liquid L flowing through the branch circulation path **32***b*. In the second modification example, by heating the processing liquid L with this heater **36**B, the processing liquid L stored in the processing tub **21** is heated up to the processing temperature required for processing the wafer W.
[0154] The filter **37**B removes contaminants such as particles contained in the processing liquid L flowing through the branch circulation path **32***b*. The filter **37**B may include multiple filter modules arranged in parallel.
[0155] The branch path **41** leading to the outer tub **21***b* of the processing tub **21** is branched from the branching portion **38**. The flowmeter **39**B measures the flow rate of the processing liquid L flowing through the branch circulation path **32***b*. A measurement value of the flow rate of the processing liquid L measured by the flowmeter **39**B is outputted to the controller **5**.
[0156] The branch path **41** is a flow path for sampling the concentration of the processing liquid L flowing through the branch circulation path **32***b*. This branch path **41** is provided with the flowmeter **42**, the concentration meter **43**, and the valve **44***a* in this order from the upstream side with respect to the branching portion **38**.
[0157] The flowmeter **42** measures the flow rate of the processing liquid L flowing through the branch path **41**. A measurement value of the flow rate of the processing liquid L measured by the flowmeter **42** is outputted to the controller **5**.
[0158] The concentration meter **43** measures the concentration of the processing liquid L flowing through the branch path **41** to measure the concentration of the processing liquid L flowing through the circulation path **32**. The concentration meter **43** measures, for example, a phosphoric acid concentration of the processing liquid L flowing through the branch path **41**. A measurement value of the concentration of the processing liquid L measured by the concentration meter **43** is outputted to the controller **5**. The valve **44** controls whether or not the processing liquid L is to be supplied from the branching portion **38** to the outer tub **21***b*.
[0159] In the processing liquid supply system **3** of the second modification example described so far, by performing the same detection processing as in the above-described exemplary embodiment, it is possible to detect abnormality in the supply of the processing liquid L in the circulation path **32** and the branch circulation paths **32***a* and **32***b*.
[0160] Further, in the example of FIG. **9** explained so far, the circulation path **32** is branched into the two branch circulation paths **32***a* and **32***b* on its way. However, the present disclosure is not limited thereto, and the circulation path **32** may be branched into three or more branch circulation paths on its way.
[0161] FIG. **10** is a block diagram showing a configuration example of the liquid processing device **2** according to a third modification example. As depicted in FIG. **10**, the liquid processing device **2**

according to the third modification example is a single-wafer processing device configured to process wafers W one by one.

[0162] The liquid processing device **2** according to the third modification example has a housing **110** whose inside is hermetically sealable. A carry-in/out opening (not shown) for carry-in/carry-out of the wafer W is formed in a side surface of the housing **110**, and an opening/closing shutter (not shown) is provided at this carry-in/out opening.

[0163] A spin chuck **120** configured to hold and rotate the wafer W is provided at a central portion within the housing **110**. The spin chuck **120** has a horizontal top surface, and a suction opening (not shown) for suctioning the wafer W is provided in the top surface. The wafer W can be attracted to and held on the spin chuck **120** by suctioning through this suction opening.

[0164] The spin chuck **120** is configured to be rotatable at a required speed by a chuck driver **121** such as, but not limited to, a motor. The chuck driver **121** is provided with an elevating mechanism such as a non-illustrated cylinder, and the spin chuck **120** is configured to be movable up and down by the elevating mechanism.

[0165] A cup **122** is disposed around the spin chuck **120** to collect the processing liquid L (see FIG. **3**) scattered or falling from the wafer W. A drain pipe **123** for draining the collected processing liquid L and an exhaust pipe **124** for exhausting an atmosphere within the cup **122** are connected to a bottom of the cup **122**.

[0166] A discharge nozzle **131** is provided at an upper portion of the housing **110**. The discharge nozzle **131** is configured to be movable from a standby section **132** provided outside the top of the cup **122** to above the center of the wafer W located inside the cup **122**. The discharge nozzle **131** is connected to the processing liquid supply system **3**, and discharges the processing liquid L supplied from the processing liquid supply system **3** onto the wafer W.

[0167] The liquid processing device **2** and the processing liquid supply system **3** according to the third modification example are controlled by the control device **4**, the same as in the above-described exemplary embodiment. The control device **4** is, for example, a computer, and includes the controller **5** and the storage **6**.

[0168] FIG. **11** illustrates a configuration example of the processing liquid supply system **3** according to the third modification example. As shown in FIG. **11**, the processing liquid supply system **3** according to the third modification example includes a processing liquid source **101** and a processing liquid supply path **102**.

[0169] The processing liquid source **101** is, for example, a tank that stores the processing liquid L (see FIG. **3**). The processing liquid supply path **102** connects the processing liquid source **101** to the discharge nozzle **131**, and supplies the processing liquid L from the processing liquid source **101** to the discharge nozzle **131**.

[0170] The processing liquid supply path **102** is provided with a valve **103**, a pump **104**, a pressure gauge **105**, a heater **106**, a filter **107**, a flowmeter **108**, and a thermometer **109** in this order from the upstream side with respect to the processing liquid source **101**.

[0171] The valve **103** controls whether or not the processing liquid L is to be supplied from the processing liquid source **101** to the discharge nozzle **131**. The pump **104** creates a flow of the processing liquid L that comes out of the processing liquid source **101**, passes through the processing liquid supply path **102**, and reaches the discharge nozzle **131**.

[0172] The pump **104** is, by way of non-limiting example, a magnetic levitation pump configured to force-feed the processing liquid L as a rotator thereof is rotated in the processing liquid L while being magnetically levitated. However, the pump **104** of the present disclosure is not limited to the magnetic levitation pump, and may be a diaphragm pump or the like.

[0173] Since the magnetic levitation pump, which has higher liquid feeding capacity than other types, is used for the pump **104**, the feed flow rate of the processing liquid L fed from the processing liquid supply path **102** to the discharge nozzle **131** can be increased.

[0174] The pressure gauge **105** measures the pressure of the processing liquid L flowing through

the processing liquid supply path **102**. A measurement value of the pressure of the processing liquid L measured by the pressure gauge **105** is outputted to the controller **5** (see FIG. **10**).
[0175] The heater **106** heats the processing liquid L flowing through the processing liquid supply path **102**. In the third modification example, by heating the processing liquid L with this heater **106**, the processing liquid L sent to the discharge nozzle **131** is heated up to a processing temperature required for processing the wafer W.
[0176] The filter **107** removes contaminants such as particles contained in the processing liquid L flowing through the processing liquid supply path **102**. The filter **107** may include multiple filter modules arranged in parallel.
[0177] The flowmeter **108** measures the flow rate of the processing liquid L flowing through the processing liquid supply path **102**. A measurement value of the flow rate of the processing liquid L measured by the flowmeter **108** is outputted to the controller **5**. The thermometer **109** measures the temperature of the processing liquid L flowing through the processing liquid supply path **102**. A measurement value of the temperature of the processing liquid L measured by the thermometer **109** is outputted to the controller **5**.
[0178] In the processing liquid supply system **3** of the third modification example described so far, by performing the same detection processing as in the above-described exemplary embodiment, it is possible to detect abnormality in the supply of the processing liquid L in the processing liquid supply path **102**.
[0179] The processing liquid supply system **3** according to one or more embodiments of the present application includes a processing liquid supply path (the circulation path **32** or the processing liquid supply path **102**), the pump **33** (**104**), the pressure gauge **34** (**105**), the flowmeter **39** (**108**), and the controller **5**. The processing liquid supply path (the circulation path **32** or the processing liquid supply path **102**) supplies the processing liquid L to a substrate processing device (the liquid processing device **2**) configured to process a substrate (the wafer W). The pump **33** (**104**) is provided in the processing liquid supply path (the circulation path **32** or the processing liquid supply path **102**). The pressure gauge **34** (**105**) and the flowmeter **39** (**108**) are provided downstream of the pump **33** (**104**) in the processing liquid supply path (the circulation path **32** or the processing liquid supply path **102**). The controller **5** controls the individual components. Also, the controller **5** detects abnormality in the supply of the processing liquid L based on a measurement value of the pressure gauge **34** (**105**) and a measurement value of the flowmeter **39** (**108**). With this configuration, abnormality in the supply of the processing liquid L can be detected.
[0180] In addition, in the processing liquid supply system **3** according to one or more embodiments of the present application, the controller **5** detects abnormality in the supply of the processing liquid L when the measurement value of the flowmeter **39** (**108**) does not change and the measurement value of the pressure gauge **34** (**105**) becomes equal to or lower than the predetermined lower limit pressure P.sub.L. This makes it possible to detect abnormality in the supply of the processing liquid L even when the flowmeter **39** is not outputting an appropriate measurement value due to adhesion of bubbles or the like.
[0181] Further, in the processing liquid supply system **3** according to one or more embodiments of the present application, the pump **33** (**104**) is a magnetic levitation pump configured to force-feed the processing liquid L as a rotator thereof is rotated in the processing liquid L while being magnetically levitated. The controller **5** performs the force-feeding of the processing liquid L while controlling the rotation speed of the rotator based on the measurement value of the flowmeter **39** (**108**). This makes it possible to increase the flow rate of the processing liquid L supplied to the liquid processing device **2**.
[0182] In addition, in the processing liquid supply system **3** according to one or more embodiments of the present application, if there is no change in the measurement value of the flowmeter **39** (**108**) during the predetermined time period D**2**, the controller **5** detects abnormality in the supply of the processing liquid L. Thus, even when the flowmeter **39** is not outputting a proper measurement

value due to adhesion of bubbles or the like, the abnormality in the supply of the processing liquid L can be detected.

[0183] Moreover, in the processing liquid supply system **3** according to one or more embodiments of the present application, the pump **33** (**104**) is a magnetic levitation pump configured to force-feed the processing liquid L as a rotator thereof is rotated in the processing liquid L while being magnetically levitated. In addition, if there is no change in the measurement value of the flowmeter **39** (**108**) during the predetermined time period D**2**, the controller **5** performs the force-feeding of the processing liquid L while fixing the rotation speed of the rotator to the preset rotation speed R**1**. This makes it possible to supply the processing liquid L to the liquid processing device **2** at a flow rate close to the processing flow rate F.sub.s even in the event of a flowmeter hold phenomenon in which an appropriate flow rate feedback control cannot be carried out.

[0184] The processing liquid supply system **3** according to one or more embodiments of the present application includes a processing liquid supply path (the circulation path **32** or the processing liquid supply path **102**), the pump **33** (**104**), the heater **36** (**106**), the pressure gauge **34** (**105**), the thermometer **45** (**109**), and the controller **5**. The processing liquid supply path (circulation path **32** or the processing liquid supply path **102**) supplies the processing liquid L to a substrate processing device (the liquid processing device **2**) configured to process a substrate (the wafer W). The pump **33** (**104**) is provided in the processing liquid supply path (the circulation path **32** or the processing liquid supply path **102**). The heater **36** (**106**) and the pressure gauge **34** (**105**) are provided downstream of the pump **33** (**104**) in the processing liquid supply path (the circulation path **32** or the processing liquid supply path **102**). The thermometer **45** (**109**) measures the temperature of the processing liquid L flowing through the processing liquid supply path (the circulation path **32** or the processing liquid supply path **102**). The controller **5** controls the individual components. Also, the controller **5** detects abnormality in the supply of the processing liquid L based on a measurement value of the pressure gauge **34** (**105**) and a measurement value of the thermometer **45** (**109**). With this configuration, abnormality in the supply of the processing liquid L can be detected.

[0185] The processing liquid supply system **3** according to one or more embodiments of the present application further includes the storage **6** that stores a monitoring table in which a pressure threshold according to the temperature of the processing liquid L is set. The controller **5** detects abnormality in the supply of the processing liquid L when the measurement value of the pressure gauge **34** (**105**) exceeds the pressure threshold according to the processing liquid L set in the monitoring table. Therefore, damage to the processing liquid supply system **3** and the liquid processing device **2** that might be caused by the abnormality in the processing liquid L can be suppressed.

[0186] The processing liquid supply system **3** according to one or more embodiments of the present application further includes the flowmeter **39** (**108**) provided downstream of the pump **33** (**104**) in the processing liquid supply path (the circulation path **32** or the processing liquid supply path **102**). The pump **33** (**104**) is a magnetic levitation pump configured to force-feed the processing liquid L as a rotator thereof is rotated in the processing liquid L while being magnetically levitated. The controller **5** performs the force-feeding of the processing liquid L while controlling the rotation speed of the rotator based on a measurement value of the flowmeter **39** (**108**). Thus, the force-feed flow rate of the processing liquid L supplied to the liquid processing device **2** can be increased.

[0187] In addition, in the processing liquid supply system **3** according to one or more embodiments of the present application, when the controller **5** detects the abnormality in the supply of the processing liquid L, it stops the rotation of the rotator of the pump **33** (**104**) to stop the force-feeding of the processing liquid L. This makes it possible to suppress damage to the processing liquid supply system **3** and the liquid processing device **2** that might be caused by the abnormality in the supply of the processing liquid L.

<Sequence of Control Processing>

[0188] Now, a sequence of a control processing according to one or more embodiments of the present application will be explained with reference to FIG. **12** and FIG. **13**. FIG. **12** is a flowchart showing an example of a sequence of a control processing performed by the processing liquid supply system **3** according to one or more embodiments of the present application.

[0189] In the control processing according to the example of FIG. **12**, the controller **5** first operates the pump **33** to allow the processing liquid L to flow through the circulation path **32**, thus allowing the processing liquid L to be supplied to the liquid processing device **2** (process S**101**).

[0190] Then, the controller **5** determines whether or not there is a change in a measurement value of the flowmeter **39** (process S**102**). For example, the controller **5** may make a determination that there is no change in the measurement value of the flowmeter **39** if the current measurement value of the flowmeter **39** is the same as the previous measurement value.

[0191] Then, when it is determined that there is no change in the measurement value of the flowmeter **39** (process S**102**, Yes), the controller **5** determines whether or not the measurement value of the pressure gauge **34** is equal to or less than the lower limit pressure P.sub.L (process S**103**).

[0192] Then, when it is determined that the measurement value of the pressure gauge **34** is equal to or less than the lower limit pressure P.sub.L (process S**103**, Yes), the controller **5** detects abnormality in the supply of the processing liquid L in the circulation path **32** (process S**104**).

[0193] Meanwhile, if it is determined that the measurement value of the pressure gauge **34** is not equal to or less than the lower limit pressure P.sub.L (process S**103**, No), the processing returns back to the process S**101**. Also, if it is determined in the process S**102** that there is a change in the measurement value of the flowmeter **39** (process S**102**, No), the processing returns back to the process S**101**.

[0194] Following the process S**104**, the controller **5** determines whether the state in which the measurement value of the pressure gauge **34** is equal to or less than the lower limit pressure P.sub.L lasts for the predetermined time period D**1** (process S**105**).

[0195] Then, when it is determined that the state in which the measurement value of the pressure gauge **34** is equal to or less than the lower limit pressure P.sub.L lasts for the predetermined time period D**1** (process S**105**, Yes), the controller **5** stops the supply processing and the temperature control processing for the processing liquid L (process S**106**), and ends the series of processes of the detection processing.

[0196] Meanwhile, if it is determined that the state in which the measurement value of the pressure gauge **34** is equal to or less than the lower limit pressure P.sub.L does not last for the predetermined time period D**1** (process S**105**, No), the processing returns back to the process S**102**.

[0197] FIG. **13** is a flowchart showing an example of a sequence of a control processing performed by the processing liquid supply system **3** according to one or more embodiments of the present application.

[0198] In the control processing according to the example of FIG. **13**, the controller **5** first operates the pump **33** under a flow rate feedback control, thus allowing the processing liquid L to be supplied to the liquid processing device **2** (process S**201**).

[0199] Then, the controller **5** determines whether or not there is a change in the measurement value of the flowmeter **39** (process S**202**). By way of example, the controller **5** may make a determination that there is no change in the measurement value of the flowmeter **39** when the current measurement value of the flowmeter **39** is the same as the previous measurement value.

[0200] Then, when it is determined that there is no change in the measurement value of the flowmeter **39** (process S**202**, Yes), the controller **5** determines whether or not the state in which there is no change in the measurement value of the flowmeter **39** lasts for the predetermined time period D**2** (process S**203**).

[0201] If it is determined that the state in which there is no change in the measurement value of the flowmeter **39** lasts for the predetermined time period D**2** (process S**203**, Yes), the controller **5** detects abnormality in the supply of the processing liquid L in the circulation path **32** (process

S**204**). Also, the controller **5** switches the operation mode of the pump **33** from the flow rate feedback control to a rotation speed control (process S**205**).
[0202] On the other hand, if it is determined that the state in which there is no change in the measurement value of the flowmeter **39** does not last for the predetermined time period D**2** (process S**203**, No), the processing returns back to the process S**202**.
[0203] Further, if it is determined in the process S**202** that there is a change in the measurement value of the flowmeter **39** (process S**202**, No), the processing returns back to the process S**201**.
[0204] Following the process S**205**, the controller **5** determines whether or not there is a change in the measurement value of the flowmeter **39** (process S**206**). Then, if it is determined that there is a change in the measurement value of the flowmeter **39** (process S**206**, Yes), the controller **5** switches the operation mode of the pump **33** from the rotation speed control to the flow rate feedback control (process S**207**), and ends the series of processes of the detection processing.
[0205] On the other hand, if it is determined that there is no change in the measurement value of the flowmeter **39** (process S**206**, No), the processing of the process S**206** is continued.
[0206] A processing liquid supply method according to one or more embodiments of the present application includes a detection processing (process S**104**) of detecting abnormality in the supply of the processing liquid L based on a measurement value of the pressure gauge **34** (**105**) and a measurement value of the flowmeter **39** (**108**) in the processing liquid supply system **3**. The processing liquid supply system **3** includes a processing liquid supply path (the circulation path **32** or the processing liquid supply path **102**), the pump **33** (**104**), the pressure gauge **34** (**105**), and the flowmeter **39** (**108**). The processing liquid supply path (the circulation path **32** or the processing liquid supply path **102**) supplies the processing liquid L to a substrate processing device (the liquid processing device **2**) configured to process a substrate (the wafer W). The pump **33** (**104**) is provided in the processing liquid supply path (the circulation path **32** of the processing liquid supply path **102**). The pressure gauge **34** (**105**) and the flowmeter **39** (**108**) are provided downstream of the pump **33** (**104**) in the processing liquid supply path (the circulation path **32** or the processing liquid supply path **102**). With this configuration, abnormality in the supply of the processing liquid L can be detected.
[0207] So far, one or more embodiments of the present applications of the present disclosure has been explained. However, the present disclosure is not limited to the above-described exemplary embodiments, and various changes and modifications may be made without departing from the spirit of the present disclosure.
[0208] Here, it should be noted that the above-described exemplary embodiments are illustrative in all aspects and are not anyway limiting. The above-described exemplary embodiments may be omitted, replaced and modified in various ways without departing from the scope and the spirit of claims.
[0209] According to one or more embodiments of the present application the exemplary embodiment, it is possible to detect the abnormality in the supply of the processing liquid in the processing liquid supply path.
[0210] From the foregoing, it will be appreciated that various embodiments of the present disclosure have been described herein for purposes of illustration, and that various modifications may be made without departing from the scope and spirit of the present disclosure. Accordingly, the various embodiments disclosed herein are not intended to be limiting. The scope of the inventive concept is defined by the following claims and their equivalents rather than by the detailed description of one or more embodiments of the present applications. It shall be understood that all modifications and embodiments conceived from the meaning and scope of the claims and their equivalents are included in the scope of the inventive concept.

Claims

1. A processing liquid supply system, comprising: a processing liquid supply path through which a processing liquid is supplied to a substrate processing device configured to process a substrate; a pump provided in the processing liquid supply path; a pressure gauge and a flowmeter provided downstream of the pump in the processing liquid supply path; and a controller having a processor and a memory with a computer readable program stored therein that upon execution of the computer readable program by the processor configures the controller to detect abnormality in supply of the processing liquid based on a measurement value of the pressure gauge and a measurement value of the flowmeter.
2. The processing liquid supply system of claim 1, wherein the controller detects the abnormality in the supply of the processing liquid when there is no change in the measurement value of the flowmeter and the measurement value of the pressure gauge becomes equal to or less than a preset lower limit pressure.
3. The processing liquid supply system of claim 2, wherein the pump is a magnetic levitation pump configured to force-feed the processing liquid as a rotator of the magnetic levitation pump is rotated in the processing liquid while being magnetically levitated, and the controller performs force-feeding of the processing liquid while controlling a rotation speed of the rotator based on the measurement value of the flowmeter.
4. The processing liquid supply system of claim 2, wherein the controller detects the abnormality in the supply of the processing liquid when there is no change in the measurement value of the flowmeter during a preset time period and the measurement value of the pressure gauge becomes equal to or less than a preset lower limit pressure.
5. The processing liquid supply system of claim 4, wherein the pump is a magnetic levitation pump configured to force-feed the processing liquid as a rotator of the magnetic levitation pump is rotated in the processing liquid while being magnetically levitated, and when there is no change in the measurement value of the flowmeter during the preset time period, the controller performs force-feeding of the processing liquid while fixing a rotation speed of the rotator to a predetermined rotation speed.
6. A processing liquid supply system, comprising: a processing liquid supply path through which a processing liquid is supplied to a substrate processing device configured to process a substrate; a pump provided in the processing liquid supply path; a heater and a pressure gauge provided downstream of the pump in the processing liquid supply path; a thermometer configured to measure a temperature of the processing liquid flowing through the processing liquid supply path; and a controller having a processor and a memory with a computer readable program stored therein that upon execution of the computer readable program by the processor configures the controller to detect abnormality in supply of the processing liquid based on a measurement value of the pressure gauge and a measurement value of the thermometer.
7. The processing liquid supply system of claim 6, further comprising: a storage configured to store a monitoring table in which a pressure threshold corresponding to the temperature of the processing liquid is set, wherein the controller detects the abnormality in the supply of the processing liquid when the measurement value of the pressure gauge exceeds the pressure threshold corresponding to the temperature of the processing liquid set in the monitoring table.
8. The processing liquid supply system of claim 6, further comprising: a flowmeter provided downstream of the pump in the processing liquid supply path, wherein the pump is a magnetic levitation pump configured to force-feed the processing liquid as a rotator of the magnetic levitation pump is rotated in the processing liquid while being magnetically levitated, and the controller performs force-feeding of the processing liquid while controlling a rotation speed of the rotator based on a measurement value of the flowmeter.
9. The processing liquid supply system of claim 8, wherein when the abnormality in the supply of the processing liquid is detected, the controller stops rotation of the rotator of the pump to stop the

force-feeding of the processing liquid.

10. A processing liquid supply method performed in a processing liquid supply system, wherein the processing liquid supply system comprises: a processing liquid supply path through which a processing liquid is supplied to a substrate processing device for processing a substrate; a pump provided in the processing liquid supply path; and a pressure gauge and a flowmeter provided downstream of the pump in the processing liquid supply path, and the processing liquid supply method comprises: detecting abnormality in supply of the processing liquid based on a measurement value of the pressure gauge and a measurement value of the flowmeter.

11. The processing liquid supply method of claim 10, further comprising detecting the abnormality in the supply of the processing liquid when there is no change in the measurement value of the flowmeter and the measurement value of the pressure gauge becomes equal to or less than a preset lower limit pressure.

12. The processing liquid supply method of claim 11, wherein the pump is a magnetic levitation pump configured to force-feed the processing liquid as a rotator of the magnetic levitation pump is rotated in the processing liquid while being magnetically levitated, and the method further comprises performing force-feeding of the processing liquid while controlling a rotation speed of the rotator based on the measurement value of the flowmeter.

13. The processing liquid supply method of claim 11, wherein the method further comprises detecting the abnormality in the supply of the processing liquid when there is no change in the measurement value of the flowmeter during a preset time period and the measurement value of the pressure gauge becomes equal to or less than a preset lower limit pressure.

14. The processing liquid supply method of claim 13, wherein the pump is a magnetic levitation pump configured to force-feed the processing liquid as a rotator of the magnetic levitation pump is rotated in the processing liquid while being magnetically levitated, and the method further comprises, when there is no change in the measurement value of the flowmeter during the preset time period, performing force-feeding of the processing liquid while fixing a rotation speed of the rotator to a predetermined rotation speed.

15. The processing liquid supply method of claim 10, further comprising: measuring, by a thermometer, a temperature of the processing liquid flowing through the processing liquid supply path; and detecting the abnormality in the supply of the processing liquid when the measurement value of the pressure gauge exceeds a pressure threshold corresponding to the temperature of the processing liquid set in a monitoring table.

16. A non-transitory computer-readable recording medium having stored thereon computer-executable instructions that, in response to execution, cause a processing liquid supply system to perform a processing liquid supply method as claimed in claim 10.

17. The non-transitory computer-readable recording medium of claim 16, wherein the method further comprises detecting the abnormality in the supply of the processing liquid when there is no change in the measurement value of the flowmeter and the measurement value of the pressure gauge becomes equal to or less than a preset lower limit pressure.

18. The non-transitory computer-readable recording medium of claim 17, wherein the pump is a magnetic levitation pump configured to force-feed the processing liquid as a rotator of the magnetic levitation pump is rotated in the processing liquid while being magnetically levitated, and the method further comprises performing force-feeding of the processing liquid while controlling a rotation speed of the rotator based on the measurement value of the flowmeter.

19. The non-transitory computer-readable recording medium of claim 17, wherein the method further comprises detecting the abnormality in the supply of the processing liquid when there is no change in the measurement value of the flowmeter during a preset time period and the measurement value of the pressure gauge becomes equal to or less than a preset lower limit pressure.

20. The computer-readable recording medium of claim 19, wherein the pump is a magnetic levitation pump configured to force-feed the processing liquid as a rotator of the magnetic levitation pump is rotated in the processing liquid while being magnetically levitated, and the method further comprises, when there is no change in the measurement value of the flowmeter during the preset time period, performing force-feeding of the processing liquid while fixing a rotation speed of the rotator to a predetermined rotation speed.