United States Patent	12394609
Kind Code	B2
Date of Patent	August 19, 2025
Inventor(s)	Okazaki; Fumiya

Product removal apparatus, treatment system, and product removal method

Abstract

The present disclosure provides a product removal apparatus, a treatment system, and a product removal method that can sufficiently remove the products deposited inside a vacuum pump and also suppress corrosion of the base material of the vacuum pump. The product removal apparatus of the present disclosure includes: a sensor for measuring the temperature of the inside of a vacuum pump, the thickness of a film of a product in a flow path in the vacuum pump, or the vibration frequency of the vacuum pump; a gas supplier for supplying a gas containing hydrogen halide, fluorine, chlorine, chlorine trifluoride, or fluorine radicals to the vacuum pump; and a control device. The control device controls the gas supplier so that the supply of the gas to the vacuum pump is stopped depending on a rate of temperature increase calculated from the temperature measured by the sensor, the film thickness, or the vibration frequency.

Inventors:	**Okazaki; Fumiya (Tokyo, JP)**
Applicant:	**EBARA CORPORATION** (Tokyo, JP)
Family ID:	**1000008765914**
Assignee:	**EBARA CORPORATION (Tokyo, JP)**
Appl. No.:	**17/935595**
Filed:	**September 27, 2022**

Prior Publication Data

Document Identifier	**Publication Date**
US 20230119979 A1	Apr. 20, 2023

Foreign Application Priority Data

JP	2021-169407	Oct. 15, 2021

Publication Classification

Int. Cl.: **H01J37/32** (20060101); **G01B21/08** (20060101); **G01K13/00** (20210101)

U.S. Cl.:

CPC **H01J37/32862** (20130101); **G01B21/08** (20130101); **G01K13/00** (20130101); **H01J37/32449** (20130101); H01J2237/335 (20130101)

Field of Classification Search

CPC: H01J (37/32862); H01J (37/32449); H01J (2237/335); G01B (21/08); G01B (11/0625); G01K (13/00); F04C (23/001); F04C (18/123); F04C (18/16); F04C (2220/30); F04C (2270/12); F04C (2270/19); F04C (2270/80); F04C (18/126); F04C (2280/02); F04C (2280/04); F04C (25/02); Y02C (20/30); C23C (16/4401); C23C (16/4404); C23C (16/4405); C23C (16/4412); F04B (37/14); F04B (49/02); F04B (49/06)

References Cited

U.S. PATENT DOCUMENTS

Patent No.	Issued Date	Patentee Name	U.S. Cl.	CPC
2005/0081790	12/2004	Konishi	118/712	C23C 14/544
2005/0241761	12/2004	Kannan	156/345.24	C23C 16/4405
2007/0093078	12/2006	Harada	257/E21.273	H01L 21/02362
2014/0251953	12/2013	Winkler	134/1.1	H01J 37/32449
2017/0067152	12/2016	Hayashi	N/A	H01L 21/67017
2017/0350395	12/2016	Schofield	N/A	C23C 16/4412
2021/0198786	12/2020	Hur	N/A	H01J 37/32862

FOREIGN PATENT DOCUMENTS

Patent No.	Application Date	Country	CPC
102008030788	12/2008	DE	N/A
3421639	12/2018	EP	N/A
H09-184075	12/1996	JP	N/A
H11-222680	12/1998	JP	N/A
2004-095698	12/2003	JP	N/A
2009-516920	12/2008	JP	N/A
2017-089462	12/2016	JP	N/A
2019-012812	12/2018	JP	N/A
2019-518327	12/2018	JP	N/A
2007/120276	12/2006	WO	N/A
2017/189194	12/2016	WO	N/A

OTHER PUBLICATIONS

Machine translation of JP 11222680 (Year: 1999). cited by examiner

---

Primary Examiner: Bergner; Erin F

Attorney, Agent or Firm: Chrisman Gallo Tochtrop LLC

Background/Summary

CROSS-REFERENCE TO RELATED APPLICATION
(1) This application is based upon and claims benefit of priority from Japanese Patent Application No. 2021-169407 filed on Oct. 15, 2021, the entire contents of which are incorporated herein by reference.
TECHNICAL FIELD
(2) The present invention relates to a product removal apparatus, a treatment system, and a product removal method.
BACKGROUND ART
(3) Vacuum pumps are widely used as part of equipment for manufacturing semiconductors, liquid crystals, solar panels, LEDs, and other items. In a process of manufacturing any of these items, a vacuum pump is connected to the chamber of a semiconductor treatment apparatus to intake the process gas in the chamber and create a vacuum environment in the chamber. The process gas used to process a semiconductor may contain a gas producing products. For this reason, when the gas flows from the chamber to the vacuum pump, products may be generated in the flow path in the vacuum pump. If the products are trapped in the gap between the rotors of the vacuum pump, or in the gap between the rotor and the casing that houses the rotor, the products may interfere with the normal rotation of the vacuum pump. There has therefore been a need to remove the products deposited inside the vacuum pump.
(4) A known invention that solves such a problem is the exhaust equipment system disclosed in PTL 1. PTL 1 discloses, as shown in FIG. **1** and other drawings therein, an exhaust equipment system having exhaust equipment for exhausting the gas from the chamber of a manufacturing apparatus, and a gas supplier. The gas supplier is configured to supply gas containing at least one substance selected from the group consisting of hydrogen halide, fluorine, chlorine, chlorine trifluoride, and fluorine radicals to the exhaust equipment. Thus, this exhaust equipment system reacts the products deposited inside the vacuum pump and the like included in the exhaust equipment with the gas containing at least one substance selected from the group consisting of hydrogen halide, fluorine, chlorine, chlorine trifluoride, and fluorine radicals, thereby removing the products.
CITATION LIST
Patent Literature
(5) PTL 1: Japanese Patent Laid-Open No. 2019-12812
SUMMARY OF INVENTION
Technical Problem
(6) By the way, the exhaust equipment system disclosed in PTL 1 does not disclose anything about the amount of the gas, containing at least one substance selected from the group consisting of hydrogen halide, fluorine, chlorine, chlorine trifluoride, and fluorine radicals, that the gas supplier supplies to the exhaust equipment. Hydrogen halide, fluorine, chlorine, chlorine trifluoride, and fluorine radicals remove products deposited in the vacuum pump but may also etch the base material of the vacuum pump. Therefore, if too much hydrogen halide, fluorine, chlorine, chlorine trifluoride, or fluorine radical is supplied to the vacuum pump, the base material of the vacuum pump may be corroded by over-etching, requiring early replacement of the base material. If too little hydrogen halide, fluorine, chlorine, chlorine trifluoride, or fluorine radical is supplied to the vacuum pump, there is a risk that the products deposited in the vacuum pump are not sufficiently removed. In this case, the products may be trapped in the gap between the rotors of the vacuum

pump, or in the gap between the rotor and the casing that houses the rotor, and may interfere with the normal rotation of the vacuum pump.
(7) To solve the aforementioned problems, one object of the present invention is to provide a product removal apparatus, a treatment system, and a product removal method that can sufficiently remove the products deposited inside the vacuum pump and also suppress corrosion of the base material of the vacuum pump.
Solution to Problem
(8) A product removal apparatus according to one embodiment includes: a sensor for measuring the temperature of the inside of a vacuum pump, the thickness of a film of a product in a flow path in the vacuum pump, or the vibration frequency of the vacuum pump; a gas supplier for supplying a gas containing hydrogen halide, fluorine, chlorine, chlorine trifluoride, or fluorine radicals to the vacuum pump; and a control device. The control device controls the gas supplier so that the supply of the gas to the vacuum pump is stopped depending on a rate of temperature increase calculated from the temperature measured by the sensor, the film thickness, or the vibration frequency.
(9) A treatment system according to one embodiment includes: a chamber; the vacuum pump; a pipe for connecting the chamber to the vacuum pump; and the product removal apparatus, the apparatus being connected to the pipe.
(10) A product removal method according to one embodiment includes the steps of: supplying a gas containing hydrogen halide, fluorine, chlorine, chlorine trifluoride, or fluorine radicals to a vacuum pump; measuring the temperature inside the vacuum pump, the thickness of a film of a product in the flow path in the vacuum pump, or the vibration frequency of the vacuum pump; and stopping the supply of the gas to the vacuum pump depending on a rate of temperature increase calculated from the temperature, the film thickness, or the vibration frequency.

Description

BRIEF DESCRIPTION OF DRAWINGS
(1) FIG. **1** is a block diagram of a treatment system according to one embodiment of the present disclosure.
(2) FIG. **2** is a block diagram showing the configuration of the control device and vacuum pump shown in FIG. **1**.
(3) FIG. **3** is a structural diagram showing the configuration of the plasma source shown in FIG. **1**.
(4) FIG. **4** is a block diagram showing the configuration of a gas supplier according to another embodiment of the present disclosure.
(5) FIG. **5** is a graph showing the relationship between the time and the rate of temperature increase in the vacuum pump during the operation of the product removal apparatus shown in FIG. **1**.
(6) FIG. **6** is a graph showing the relationship between the time and the temperature in the vacuum pump during the operation of the product removal apparatus shown in FIG. **1**.
(7) FIG. **7** is a block diagram showing the configuration of the control device and vacuum pump according to another embodiment of the present disclosure.
(8) FIG. **8** is a block diagram showing the configuration of the control device and vacuum pump according to another embodiment of the present disclosure.
DESCRIPTION OF EMBODIMENTS
(9) The embodiment of the present invention will be described below with reference to the accompanying drawings. In the drawings described below, identical or equivalent components will be denoted by the same reference numerals and redundant explanations will be omitted.
(10) FIG. **1** is a block diagram of a treatment system **100** according to an embodiment of the present disclosure. Referring to FIG. **1**, the treatment system **100** includes, for example, a semiconductor treatment apparatus **110**, a product removal apparatus **200**, a detoxification device

120, a vacuum pump **150**, and multiple pipes **130** and **132**. First, the components of the treatment system **100** will be described.
(11) The semiconductor treatment apparatus **110** includes, for example, a chamber **112** and a valve **114**. The semiconductor treatment apparatus **110** is, for example, used to provide a process gas to a substrate placed in the chamber **112** and perform deposition on the substrate. The chamber **112** is connected to the pipe **130**. Accordingly, after being used for the deposition, the process gas is exhausted through the pipe **130** to the vacuum pump **150**. The valve **114** has the function of adjusting the flow rate of the process gas exhausted from the chamber **112**. A semiconductor treatment apparatus herein refers to an apparatus that performs some treatment on a substrate during semiconductor manufacturing. Examples of the semiconductor treatment apparatus include chemical vapor deposition (CVD) apparatuses and atomic layer deposition (ALD) apparatuses.
(12) The vacuum pump **150** intakes the process gas from inside the chamber **112** and is used to create a vacuum in the chamber **112**. The vacuum pump **150** is configured to increase the pressure on the intake side during intake from 100 Pa to 300 Pa. The vacuum pump **150** is also connected to the detoxification device **120** through the pipe **132**. As a result, the process gas that the vacuum pump **150** intakes from the chamber **112** flows to the detoxification device **120**. The detailed structure of the vacuum pump **150** will be described below.
(13) The detoxification device **120** has the function of detoxifying process gases by known methods. The process gas used in semiconductor treatment may include silane gas (SiH_4), dichlorosilane gas (SiH_2Cl_2), ammonia (NH_3), and other toxic flammable gases, or NF_3, ClF_3, SF_6, and CHF_3, C_2F_6, CF_4, and other halogenated persistent gases. Therefore, the process gas exhausted by the vacuum pump **150** cannot be released directly into the air, but is detoxified by the detoxification device **120**. The process gas after detoxification is released into the air.
(14) The configuration of the vacuum pump **150** will now be described with reference to FIG. **2**. FIG. **2** is a block diagram showing the configurations of the control device **500** and vacuum pump **150** shown in FIG. **1**. As shown in FIG. **2**, the vacuum pump **150** includes, for example, a first vacuum pump **160** as a booster pump, a second vacuum pump **170** as the main pump, a housing **180** for housing the first vacuum pump **160** and second vacuum pump **170**, an intake pipe **182**, a connection pipe **184**, and an exhaust pipe **186**.
(15) The first vacuum pump **160** and the second vacuum pump **170** are examples of roots vacuum pump. The first vacuum pump **160** includes a pair of roots pump rotors **162** (FIG. **2** shows only one pump rotor). The second vacuum pump **170** has, for example, a pair of roots pump rotors **172** (FIG. **2** shows only one pump rotor).
(16) An intake pipe **182** is provided at the intake of the first vacuum pump **160**, and this intake pipe **182** is connected to the chamber **112** through the pipe **130** (see FIG. **1**). An exhaust port is provided downstream from the first vacuum pump **160**, and this exhaust port is connected to the intake of the second vacuum pump **170** through the connection pipe **184**. The exhaust pipe **186** is connected to the exhaust port of the second vacuum pump **170**, and this exhaust pipe **186** is connected to the detoxification device **120** through the pipe **132** (see FIG. **1**). Thus, the first vacuum pump **160** and the second vacuum pump **170** are connected in series, and the second vacuum pump **170** is located downstream from the first vacuum pump **160**. In other words, the first vacuum pump **160** is located on the vacuum side compared with the second vacuum pump **170** and the second vacuum pump **170** is located on the air side.
(17) As shown in FIG. **2**, the first vacuum pump **160** has a pair of opposed multistage pump rotors **162**, a motor M**1**, and a casing **168**. Each pump rotor **162** has a first-stage roots rotor (rotor) **164***a* located on the intake side, a second-stage roots rotor (rotor) **164***b* located on the exhaust side, and a rotary shaft **166** to which these roots rotors **164***a* and **164***b* are fixed. The motor M**1** is fixed to the end of the rotary shaft **166**. The casing **168** houses the roots rotors **164***a* and **164***b*. Additionally, a small gap is formed between the roots rotors **164** and between each roots rotor **164** and the inner

surface of the casing **168** in order to make the roots rotor **164** rotatable on a noncontact basis within the casing **168**. Rotation of the motor M**1** allows the first vacuum pump **160** to intake gas through the intake.

(18) The second vacuum pump **170** differs from the first vacuum pump **160** in that it has a five-stage pump rotor **172**. The other configuration of the second vacuum pump **170** is similar to that of the first vacuum pump **160**, and their redundant explanations will be omitted. As shown in FIG. **2**, the second vacuum pump **170** includes a pair of opposed multistage pump rotors **172**, a motor M**2**, and a casing **178**. Each pump rotor **172** has a first-stage roots rotor (rotor) **174***a*, a second-stage roots rotor (rotor) **174***b*, a third-stage roots rotor (rotor) **174***c*, a fourth stage roots rotor (rotor) **174***d*, and a fifth stage roots rotor (rotor) **174***e*, which are located from the intake side to the exhaust side in this order, and a rotary shaft **176** to which these roots rotors are fixed. The motor M**2** is fixed to the end of the rotary shaft **176**. Additionally, a small gap is formed between the roots rotors **174** and between each roots rotor **174** and the inner surface of the casing **178** in order to make the roots rotor **174** rotatable on a noncontact basis within the casing **178**. Rotation of the motor M**2** allows the second vacuum pump **170** to intake gas through the intake.

(19) In another embodiment of the present disclosure, the vacuum pump **150** may include screw, claw, or other types of vacuum pumps instead of roots vacuum pumps. Even in this case, a multi-stage pump rotor in which multiple stages of rotors are aligned in the axial direction may be used. The number of stages of pump rotors **162** and **172** should not necessarily be 2 or 5 and may be three or more, or five or more or five or less.

(20) As mentioned above, the intake pipe **182** is connected to the chamber **112** (see FIGS. **1** and **2**). As a result, the process gas exhausted from the chamber **112** flows through the flow paths in the first vacuum pump **160** and the flow paths in the second vacuum pump **170**. The process gas used in the semiconductor treatment step can contain components that solidify or liquefy as the temperature of the gas decreases. Therefore, when the temperature of the process gas drops as it flows through the flow path in the vacuum pump **150**, the process gas may solidify or liquefy, and a product may be deposited in the flow paths in the vacuum pump **150**. In other words, this product can be deposited in the gap between the roots rotors **164** and **174** and the gap between each of the roots rotors **164** and **174** and the inner surface of the casings **168** and **178**. In such cases, the products can interfere with the rotation of the pump rotors **162** and **174** and cause the motors M**1** and M**2** to heat up due to excessive load on the motors M**1** and M**2**. There is also a risk that the starting torque of the motors M**1** and M**2** will not be enough to rotate the pump rotors **162** and **174**. For this reason, removal of the products deposited inside the vacuum pump **150** is required. The treatment system **100** includes a product removal apparatus **200** to address this problem. In the present disclosure, “inside the vacuum pump **150**” and “in the vacuum pump **150**” refer to inside the housing **180** of the vacuum pump **150**.

(21) Referring back to FIG. **1**, the product removal apparatus **200** includes a gas supplier **300**. The gas supplier **300** includes a plasma source **310** and a pipe **340**. Refer now to FIG. **3**. FIG. **3** is a structural diagram showing the configuration of the plasma source **310** shown in FIG. **1**. Referring to FIG. **3**, the plasma source **310** includes a ceramic tube **312** and a coil **314** wound around the ceramic tube **312**. The plasma source **310** is configured to generate plasma **316** inside the ceramic tube **312** when a high frequency is applied to the coil **314**. Note that the coil **314** is composed of copper (Cu), for example, and the ceramic tube **312** is composed of, for example, at least one material selected from the group consisting of: aluminum nitride (AlN), alumina (Al.sub.2O.sub.3), zirconium oxide (ZrO.sub.2), hafnium oxide (HfO.sub.2), and yttria (Y.sub.2O.sub.3).

(22) The plasma source **310** is connected to an etching gas supply source **902** and an argon gas supply source **904** (see FIG. **1**). The etching gas supply source **902** is configured to supply etching gas to the plasma source **310**. The etching gas contains nitrogen trifluoride (NF.sub.3), sulfur hexafluoride (SF.sub.6), and carbon tetrafluoride (CF.sub.4). Meanwhile, the argon gas supply source **904** is configured to supply argon (Ar) gas to the plasma source **310**. The etching gas and

argon gas are mixed in the plasma source **310** and a plasma is applied to this mixed gas. Consequently, the plasma source **310** generates fluorine radical gas from the etching gas including nitrogen trifluoride, sulfur hexafluoride, and carbon tetrafluoride. Note that the argon gas is widely used as a gas to ignite the plasma, and is used to ensure the stability of the plasma discharge. The fluorine radical thus generated is supplied to the vacuum pump **150** through the pipes **340** and **130** (see FIG. **1**).

(23) As mentioned above, a product may be deposited inside the vacuum pump **150**, but the products produced from the process gas is mostly silicon dioxide (SiO_2). Silicon dioxide and fluorine radicals react as shown in the following chemical equation. In the chemical equation, one molecule of fluorine radical is expressed as FR.

$SiO_2+4FR \rightarrow SiF_4+O_2$

(24) As can be seen from this chemical equation, when silicon dioxide reacts with a fluorine radical, silicon fluoride (SiF_4) and oxygen (O_2) are generated. Silicon fluoride, which has a low boiling point and sublimates at −95.5° C., is easily removed in gaseous form at room temperature. Accordingly, the fluorine radical supplied to the vacuum pump **150** removes the products deposited inside the vacuum pump **150**. In other words, the product removal apparatus **200** has the function of removing the products deposited inside the vacuum pump **150**, using fluorine radicals. Although the products can contain tungsten (W)-based products and silicon carbide (SiC), these products can also be removed using fluorine radicals.

(25) Referring again to FIG. **1**, the gas supplier **300** has a reducer **320** located downstream from the plasma source **310**. The reducer **320** is configured to maintain the pressure inside the plasma source **310** at 10 Torr or higher. If the pressure controlling reducer **320** is not present between the vacuum pump **150** and the plasma source **310**, when the vacuum pump **150** intakes gas, the pressure inside the plasma source **310** will be lower than with the reducer **320**. If the pressure inside the plasma source **310** drops too much, there is a risk that the plasma source **310** will not generate plasma. In contrast, the gas supplier **300** includes the reducer **320** configured to maintain the pressure inside the plasma source **310** at 10 Torr or higher. As a result, even when the vacuum pump **150** is intaking gas, the plasma source **310** can stably generate plasma **316**.

(26) The pipe **340** located downstream from the plasma source **310** is coated with aluminum oxide or insulator. Consequently, fluorine radicals flowing through the pipe **340** are made less prone to deactivation than those flowing through a pipe that is not coated with aluminum oxide or insulator.

(27) The gas supplier **300** also includes a valve **330** attached to the pipe **340**. The valve **330** has the function of adjusting the flow rate of the gas flowing through the pipe **340**. The valve **330** is used to stop the supply of the gas from the plasma source **310** to the vacuum pump **150**. The valve **330** is also used to prevent gas released from chamber **112** from entering the plasma source **310** and to prevent gas from flowing from the plasma source **310** into the vacuum pump **150** in the event of a failure of the vacuum pump **150**.

(28) In another embodiment of the present disclosure, the product removal apparatus **200** may include a plasma source that generates fluorine radicals by, instead of using the plasma source **310**, generating plasma in another known manner. For example, the plasma source may generate plasma by barrier discharge, creepage discharge, high frequency discharge, or the like to produce fluorine radicals.

(29) In another embodiment of the present disclosure, the product removal apparatus **200** may include, instead of the gas supplier **300**, a gas supplier **360** configured to supply hydrogen halide, fluorine, chlorine, and chlorine trifluoride to the vacuum pump **150**. FIG. **4** is a block diagram showing the configuration of the gas supplier **360**.

(30) Referring to FIG. **4**, the gas supplier **360** includes two mass flow controllers **362***a* and **362***b*, valves **364**, and a pipe **370**. The mass flow controller **362***a* is connected to a gas supply source **906** via a pipe **366** and has the function of controlling the flow rate of gas supplied from the gas supply source **906**. The gas supply source **906** supplies hydrogen halide, fluorine, chlorine, or chlorine

trifluoride to the mass flow controller **362***a*. On the other hand, the mass flow controller **362***b* is connected to a nitrogen gas supply source **908** and has the function of controlling the flow rate of gas supplied from the nitrogen gas supply source **908** through the pipe **368**. The nitrogen gas supply source **908** supplies nitrogen (N.sub.2) to the mass flow controller **362***b*. The valves **364** are used to open and close the pipes. With this configuration, the gas supplier **360** can adjust the concentration of hydrogen halide, fluorine, chlorine, and chlorine trifluoride with nitrogen and supply the concentration-adjusted hydrogen halide, fluorine, chlorine, or chlorine trifluoride to the vacuum pump **150**. It is known that hydrogen halide, fluorine, chlorine, and chlorine trifluoride can decompose silicon dioxide contained in the products. For this reason, even if the product removal apparatus **200** includes a gas supplier **360** instead of a gas supplier **300**, the product removal apparatus **200** can still remove the product inside the vacuum pump **150**.
(31) An example of the configuration of the gas supplier **360** has been described above. However, the gas supplier **360** should not necessarily have the aforementioned configuration as long as it is configured to supply hydrogen halide, fluorine, chlorine, or chlorine trifluoride to the vacuum pump **150**. For example, the gas supplier **360** may contain a cylinder filled with hydrogen halide, fluorine, chlorine, or chlorine trifluoride and supply the hydrogen halide, fluorine, chlorine, or chlorine trifluoride in the cylinder to the vacuum pump **150**.
(32) As mentioned above, the present disclosure discloses supplying hydrogen halide, fluorine, chlorine, or chlorine trifluoride to the vacuum pump **150** and supplying fluorine radicals to the vacuum pump **150**, although it is more preferable to supply fluorine radicals to the vacuum pump **150**. Fluorine radicals are more efficient at etching than hydrogen halide, fluorine, chlorine, or chlorine trifluoride and require less volume of gas to remove products. In other words, when the same volume of gas is supplied, fluorine radicals can remove products in a shorter time than hydrogen halide, fluorine, chlorine, or chlorine trifluoride. Upon supply of hydrogen halide, fluorine, chlorine, chlorine trifluoride, or fluorine radicals to the vacuum pump **150**, the operation of the semiconductor treatment apparatus **110** is stopped. For this reason, in order to shorten the downtime, it is preferable that fluorine radicals, which are efficient at etching, be supplied to the vacuum pump **150**.
(33) As described above, the product removal apparatus **200** according to the present disclosure removes the products deposited in the vacuum pump **150**, using hydrogen halide, fluorine, chlorine, chlorine trifluoride, or fluorine radicals. These gases may also etch the base material that constitutes the vacuum pump **150** when removing the products. For this reason, if too much hydrogen halide, fluorine, chlorine, chlorine trifluoride, or fluorine radicals are supplied to the vacuum pump **150**, the base material that constitutes the vacuum pump **150** can be corroded by over-etching. Also, if too little hydrogen halide, fluorine, chlorine, chlorine trifluoride, or fluorine radicals are supplied to the vacuum pump **150**, there is a risk that the products deposited in the vacuum pump **150** are not sufficiently removed. However, the product removal apparatus **200** has the configuration described below to address such problems, and the treatment system **100** prevents the occurrence of such problems.
(34) Referring again to FIG. **1**, the product removal apparatus **200** has a sensor **400** and a control device **500**. Referring to FIG. **2**, the sensor **400** has, for example, two temperature sensors **420***a* and **420***b* for measuring the temperature of the inside of the vacuum pump **150**. The temperature sensors **420***a* and **420***b* are a thermocouple, for example. Note that the two temperature sensors **420***a* and **420***b* may measure the temperature of the gas inside the vacuum pump **150** and determine it as the temperature of the inside of the vacuum pump **150**, or measure the temperature of a part of the vacuum pump **150** and determine it as the temperature of the inside of the vacuum pump **150**. In particular, the two temperature sensors **420***a* and **420***b* preferably measure the temperatures of the casings **168** and **178** and determine it as the temperature of the inside of the vacuum pump **150**. The control device **500** is also configured to calculate the rate of temperature increase, from the temperatures measured by the at least one of the temperature sensors **420***a* and **420***b*. Furthermore,

the control device **500** is configured to control the gas supplier **300** so that the supply of gas to the vacuum pump **150** is stopped when the rate of temperature increase begins to decrease. Note that the rate of temperature increase E is determined, for example, by the following equation.

$E=(T2-T1)/\Delta t$

(35) Here, T**1** is a temperature measured at a certain time and T**2** is a temperature measured Δt seconds after the certain time.

(36) The operation of the product removal apparatus **200** during product removal will now be explained. When the product removal apparatus **200** starts operating, the control device **500** first causes the plasma source **310** to generate fluorine radicals. Next, the control device **500** opens the valve **330**. This supplies fluorine radicals to the vacuum pump **150** and removes the products inside the vacuum pump **150**. At this time, the control device **500** receives the temperature of the inside of the vacuum pump **150** from the temperature sensors **420***a* and **420***b* and calculates the rate of temperature increase. When the rate of temperature increase begins to decrease, the control device **500** controls the valve **330** so that the gas supplier **300** stops the supply of gas to the vacuum pump **150**. Note that the control device **500** may send a signal to the plasma source **310** to stop the plasma generation and instruct the plasma source **310** to stop generating plasma, thereby making the gas supplier **300** stop the supply of gas to the vacuum pump **150**. This allows the product removal apparatus **200** to suppress corrosion due to over-etching of the vacuum pump **150** while sufficiently removing the products deposited inside the vacuum pump **150**. The reasons will be explained below.

(37) The products inside the vacuum pump **150** generate reaction heat as they react with fluorine radicals. For this reason, as the products inside the vacuum pump **150** decrease, the reaction heat decreases and the rate of temperature increase inside the vacuum pump **150** decreases. In particular, when the products inside the vacuum pump **150** are sufficiently removed, the rate of temperature increase inside the vacuum pump **150** decreases. In other words, the amount of products inside the vacuum pump **150** can be estimated from the rate of temperature increase inside the vacuum pump **150**.

(38) This means that with a decrease in the rate of temperature increase as a trigger, the control device **500** instructs the gas supplier **300** to stop the supply of gas to the vacuum pump **150**, so that the product removal apparatus **200** can suppress corrosion of the vacuum pump **150** due to over-etching while sufficiently removing the products deposited inside the vacuum pump **150**.

(39) Thus, in the product removal apparatus **200**, the control device **500** controls the gas supplier **300** not based on the temperature itself measured by the temperature sensors **420***a* and **420***b* but based on the rate of temperature increase calculated from this temperature. The reason for this will be explained below. FIG. **5** is a graph showing the relationship between the time and the rate of temperature increase in the vacuum pump **150** during the operation of the product removal apparatus **200**. FIG. **6** is a graph showing the relationship between the time and the temperature in the vacuum pump **150** during the operation of the product removal apparatus **200**. Referring to FIG. **5**, the rate of temperature increase starts to decrease at the time t. The decrease in the rate of temperature increase at the time t triggers the suspension of the supply of fluorine radicals. FIG. **6** shows that the temperature inside the vacuum pump **150** continues to rise at or after the time t, even though the fluorine radical supply is stopped and no reaction heat is generated. This is because the gas is compressed inside the vacuum pump **150** and compression heat is generated even after the reaction heat is no longer generated. In other words, the temperature inside the vacuum pump **150** depends not only on the reaction heat but also on the compression heat. It is therefore difficult to estimate the amount of product inside the vacuum pump **150** from only the temperature inside the vacuum pump **150** at a certain time. In other words, if suspension of the fluorine radicals is controlled based only on the temperature at a certain time, there is a risk that the products deposited inside the vacuum pump **150** are not sufficiently removed while the corrosion due to over-etching is suppressed. Therefore, the control device **500** controls the gas supplier **300** not based on the

temperature itself but based on the rate of temperature increase.
(40) In the examples shown in FIGS. **5** and **6**, the rate of temperature increase is a positive value. In other words, the control device **500** stops the supply of fluorine radicals when the rate of temperature increase is a positive value, with a decrease in the rate of temperature increase as a trigger. However, the present disclosure is not limited to this example. In another embodiment of the present disclosure, the control device **500** may trigger a decrease in the rate of temperature increase to stop the supply of fluorine radicals when the rate of temperature increase is a negative value.
(41) Even when the rate of temperature increase starts to decrease, a certain amount of product may remain inside the vacuum pump **150**. For this reason, in another embodiment of the present disclosure, the control device **500** may control the gas supplier **300** so that the supply of fluorine radicals to the vacuum pump **150** is stopped when the rate of temperature increase decreases from a predetermined threshold or above to this threshold or below. In other words, the control device **500** may be configured to control the gas supplier **300** so that the supply of fluorine radicals to the vacuum pump **150** is stopped when the rate of temperature increase decreases from a predetermined value or above to the value or below. As the products inside the vacuum pump **150** decrease, the reaction heat decreases and the rate of temperature increase further drops. Accordingly, when the rate of temperature increase decreases from a predetermined value or above to the value or below, it triggers the suspension of the supply of fluorine radicals to the vacuum pump **150**, thereby allowing the product removal apparatus **200** to sufficiently remove more products deposited inside the vacuum pump **150**.
(42) Although the case where the gas supplier **300** supplies fluorine radicals to the vacuum pump **150** has been described above as an example, even if hydrogen halide, fluorine, chlorine, or chlorine trifluoride is supplied to the vacuum pump **150**, the control device **500** performs the same control and thus produces the same effects.
(43) Referring again to FIG. **2**, the temperature sensor **420***a* includes a temperature measuring section **422***a*. The temperature sensor **420***b* includes a temperature measuring section **422***b*. The temperature measuring section **422***a* is located between the roots rotor **164** and the casing **168** so as not to interfere with the rotation of the roots rotor **164**. The temperature measuring section **422***b* is located between the roots rotor **174** and the casing **178** so as not to interfere with the rotation of the roots rotor **174**. This allows the temperature sensors **420***a* and **420***b* to measure the temperatures of the gas in the vicinities of the roots rotors **164** and **174**, or the temperatures of the casings **168** and **178**, respectively.
(44) In another embodiment of the present disclosure, the temperature measuring section **422***a* of the temperature sensor **420***a* is located downstream from the downstream roots rotor **164***b* and measures the temperature of the gas at this location. The temperature measuring section **422***b* of the temperature sensor **420***b* is located downstream from the most downstream roots rotor **174***e* and measures the temperature of the gas at this location. This allows the product removal apparatus **200** to stop the supply of fluorine radicals to the vacuum pump **150** based on the rate of temperature increase obtained downstream from the roots rotor **164***b* or roots rotor **174***e*. The temperature obtained downstream from a rotor is greatly affected by the heat of reaction between the products deposited on the rotor and fluorine radicals. This is because the gas immediately after being heated by the reaction heat between the fluorine radicals and the products deposited on the rotor flows downstream from the rotor and greatly affects the temperature obtained downstream from the rotor. Thus, the amount of products deposited on the rotor can be estimated from the temperature obtained downstream from the rotor. In other words, the product removal apparatus **200** can sufficiently remove especially the products deposited on the roots rotors **164***b* and **164***e* while suppressing corrosion due to over-etching of the roots rotors **164***b* and **164***e*. This ensures avoidance of the problem that the products are deposited in small gaps between the roots rotors **164** and **174** and between each of the roots rotors **164** and **174** and the inner surface of the casings **168**

and **178** and interfere with the rotation of the pump rotors **162** and **174**. In another embodiment of the present disclosure, the temperature measuring section **422***a* may be located downstream from the roots rotor **164***a*, and the temperature measuring section **422***b* may be located downstream from the roots rotors **174***a*, **174***b*, **174***c*, and **174***d*. In yet another embodiment of the present disclosure, the temperature measuring sections **422***a* and **422***b* may be located at any point inside the housing **180** of the vacuum pump **150**.

(45) In another embodiment of the present disclosure, the sensor **400** may include optical film thickness gauges (film thickness gauges) **440***a* and **440***b* for measuring product film thickness of the products. FIG. **7** is a block diagram showing the configurations of the control device **500** in which the sensor **400** includes two optical film thickness gauges **440***a* and **440***b*, and the vacuum pump **150**. Referring to FIG. **7**, the two optical film thickness gauges **440***a* and **440***b* include incident optical fibers **442***a* and **442***b* and light-receiving fibers **444***a* and **444***b*, respectively. The light-receiving fibers **444***a* and **444***b* are configured to be able to receive reflected light from the light emitted by the incident optical fibers **442***a* and **442***b*, respectively. The optical film thickness gauges **440***a* and **440***b* are configured to determine product film thicknesses based on the reflected light received by the light-receiving fibers **444***a* and **444***b* in a known manner. In this way, the optical film thickness gauge **440** can measure the film thickness of the products in the vacuum pump **150**.

(46) The optical film thickness gauges **440***a* and **440***b* may be configured to measure the thickness of the products at any location in the flow path within the vacuum pump **150**. However, the optical film thickness gauges **440***a* and **440***b* are preferably configured to measure the film thickness of the products deposited in the intake pipe **182** or casings **168** and **178**. The optical film thickness gauges **440***a* and **440***b* generally offer higher measurement accuracy when determining the film thickness from light incident and reflected perpendicularly to the measurement plane than when determining the film thickness from light incident and reflected in other directions. The intake pipe **182** and casings **168** and **178** are stationary. The intake pipe **182** and casings **168** and **178** also have a space wide enough to place the incident optical fibers **442***a* and **442***b* and light-receiving fibers **444***a* and **444***b*. Consequently, the incident optical fibers **442***a* and **442***b* and the light-receiving fibers **444***a* and **444***b* can be placed inside the intake pipe **182** or casings **168** and **178** so that the light-receiving fibers **444***a* and **444***b* can receive light incident and reflected perpendicularly to the measurement plane. For this reason, the optical film thickness gauges **440***a* and **440***b* are preferably configured as described above.

(47) In the embodiment related to FIG. **7**, the control device **500** is configured to control the gas supplier **300** so that the supply of fluorine radicals to the vacuum pump **150** is stopped when the product film thickness measured with at least one of the optical film thickness gauges **440***a* and **440***b* falls to or below a predetermined thickness. In other words, when the product film thickness in the vacuum pump **150** falls to or below the predetermined thickness, the supply of fluorine radicals to the vacuum pump **150** is stopped. This suppresses corrosion of the vacuum pump **150** due to over-etching.

(48) In another embodiment of the present disclosure, as shown in FIG. **8**, the sensor **400** may include a vibration measuring instrument **450** for measuring the vibration frequency of the vacuum pump **150**. In this case, the control device **500** is configured to control the gas supplier **300** so that the supply of fluorine radicals to the vacuum pump **150** is stopped when the vibration frequency measured with the vibration measuring instrument **450** falls within a predetermined range. Such control by the control device **500** suppresses corrosion of the vacuum pump **150** due to over-etching. The reason will be explained below.

(49) When there is no products deposited inside the vacuum pump **150**, the vacuum pump **150** vibrates stably at a substantially constant frequency. In other words, the vibration frequency of the vacuum pump **150** is within a certain predetermined range. In contrast, if products are deposited inside the vacuum pump **150**, the products deposited on parts cause friction between the parts

during the rotation of the roots rotors **164** and **174**. This causes the vacuum pump **150** to vibrate at a different frequency than it would if there were no products deposits thereinside. In particular, the frequency of vibration of the vacuum pump **150** is outside the predetermined range described above. In other words, when the frequency of vibration of the vacuum pump **150** is within the predetermined range, there are little products inside the vacuum pump **150** and when the frequency of vibration of the vacuum pump **150** is outside the predetermined range, there are much products inside the vacuum pump **150**. In the embodiment related to FIG. **8**, when the vibration frequency measured by the vibration measuring instrument **450** falls within the predetermined range, the supply of fluorine radicals to the vacuum pump **150** is stopped. This suppresses corrosion of the vacuum pump **150** due to over-etching. For example, the predetermined range may be from +5% to −5% of the vibration frequency when no products is deposited.

(50) Note that the vibration measuring instrument **450** may be configured to measure vibrations at any location in the vacuum pump **150**. For example, the vibration measuring instrument **450** may measure the vibrations of the housing **180**, motor M**1**, and motor M**2**.

(51) As mentioned above, in the embodiment related to FIG. **2**, the sensor **400** includes temperature sensors **420***a* and **420***b*. In the embodiment related to FIG. **7**, the sensor **400** includes optical film thickness gauges **440***a* and **440***b*. In the embodiment related to FIG. **8**, the sensor **400** includes a vibration measuring instrument **450**. In other words, these disclose examples where the sensor **400** includes a sensor based on a single method. However, the present disclosure should not necessarily be like in these examples. In another embodiment of the present disclosure, the sensor **400** may selectively include temperature sensors **420***a* and **420***b*, optical film thickness gauges **440***a* and **440***b*, and a vibration measuring instrument **450**, in combination, as needed.

APPENDICES

(52) Some or all of the aforementioned embodiments may also be described as, but not limited to, the following notes.

Appendix 1

(53) A product removal apparatus according to Appendix 1 includes: a sensor for measuring the temperature of the inside of a vacuum pump, the thickness of a film of a product in a flow path in the vacuum pump, or the vibration frequency of the vacuum pump; a gas supplier for supplying a gas containing hydrogen halide, fluorine, chlorine, chlorine trifluoride, or fluorine radicals to the vacuum pump; and a control device. The control device controls the gas supplier so that the supply of the gas to the vacuum pump is stopped depending on a rate of temperature increase calculated from the temperature measured by the sensor, the film thickness, or the vibration frequency.

(54) Silicon dioxide (SiO.sub.2) or silicon carbide (SiC) may be deposited inside the vacuum pump connected to the semiconductor treatment apparatus. The product removal apparatus according to Appendix 1 can supply hydrogen halide, fluorine, chlorine, chlorine trifluoride, or fluorine radicals to the vacuum pump, and react the products with hydrogen halide, fluorine, chlorine trifluoride, or fluorine radicals, thereby removing the products inside the vacuum pump.

(55) The products inside the vacuum pump react with hydrogen halide, fluorine, chlorine, chlorine trifluoride, or fluorine radicals, which generates reaction heat. Therefore, as the products inside the vacuum pump decrease, the reaction heat decreases and the rate of temperature increase inside the vacuum pump decreases. In other words, the amount of products inside the vacuum pump can be estimated from the rate of temperature increase inside the vacuum pump.

(56) If products are deposited in the vacuum pump, the products deposited on parts cause friction between the parts during the rotation of the rotors. This inhibits the rotation of the rotors and changes the vibration frequency of the vacuum pump. On the other hand, if the products are removed from the vacuum pump, the friction is eliminated and the vibration frequency of the vacuum pump reverts to its default value (the vibration frequency value obtained when no product is deposited in the vacuum pump). Therefore, the amount of products in the vacuum pump can be estimated from the vibration frequency of the vacuum pump.

(57) The product removal apparatus according to Appendix 1 is configured to stop the supply of gas containing hydrogen halide, fluorine, chlorine, chlorine trifluoride, or fluorine radicals to the vacuum pump depending on the temperature inside the vacuum pump, the product film thickness in the flow path inside the vacuum pump, or the vibration frequency of the vacuum pump. In other words, the product removal apparatus can stop providing gas containing hydrogen halide, fluorine, chlorine, chlorine trifluoride, or fluorine radicals to the vacuum pump depending on the directly measured product film thickness or estimated amount of products. As a result, the hydrogen halide, fluorine, chlorine, chlorine trifluoride, or fluorine radicals are prevented from over-etching the vacuum pump. In other words, this product removal apparatus can sufficiently remove the product deposited inside the vacuum pump while suppressing corrosion due to over-etching of the vacuum pump.

Appendix 2

(58) In the product removal apparatus according to Appendix 2, in relation to the product removal apparatus of Appendix 1, the sensor includes a temperature sensor for measuring the temperature of the inside of the vacuum pump, and the control device calculates the rate of temperature increase from the temperature measured by the sensor, and controls the gas supplier so that the supply of the gas to the vacuum pump is stopped when the rate of temperature increase starts to decrease or when the rate of temperature increase decreases from a predetermined rate of temperature increase or above to the predetermined rate of temperature increase or below.

(59) Once the products in the vacuum pump are sufficiently removed and the reaction between the products and hydrogen halide, fluorine, chlorine, chlorine trifluoride, or fluorine radicals is completed, the generation of reaction heat disappears. This decreases the energy used to raise the temperature in the vacuum pump. As a result, the rate of temperature increase decreases. The product removal apparatus according to Appendix 2 stops supplying hydrogen halide, fluorine, chlorine, chlorine trifluoride, or fluorine radicals to the vacuum pump when the rate of temperature increase starts to decrease or when the rate of temperature increase decreases from a predetermined rate of temperature increase or above to the predetermined rate of temperature increase or below. In other words, in this product removal apparatus, the supply of hydrogen halide, fluorine, chlorine, chlorine trifluoride, or fluorine radicals to the vacuum pump is stopped when the products in the vacuum pump have been sufficiently removed. This means that this product removal apparatus can suppress corrosion of the vacuum pump due to over-etching.

Appendix 3

(60) In the product removal apparatus according to Appendix 3, in relation to the product removal apparatus of Appendix 2, the temperature sensor includes a temperature measuring section to be located downstream from a rotor of the vacuum pump.

(61) The temperature obtained downstream from a rotor is affected by the heat of reaction between the products deposited on the rotor and hydrogen halide, fluorine, chlorine, chlorine trifluoride, or fluorine radicals. Therefore, the amount of products deposited on the rotor can be estimated from the temperature obtained downstream from the rotor. The product removal apparatus according to Appendix 3 also stops the supply of hydrogen halide, fluorine, chlorine, chlorine trifluoride, or fluorine radicals to the vacuum pump depending on the downstream side from the rotor. Consequently, this product removal apparatus can sufficiently remove the products deposited on the rotors while suppressing especially corrosion of the rotors of the vacuum pump due to over-etching.

Appendix 4

(62) In the product removal apparatus according to Appendix 4, in relation to any one of the product removal apparatuses of Appendices 1 to 3, the sensor includes a film thickness gauge for measuring the thickness of a film of a product in the flow path in the vacuum pump. The control device controls the gas supplier so that the supply of the gas to the vacuum pump is stopped when the film thickness measured by the film thickness gauge falls to or below a predetermined

thickness.
(63) The product removal apparatus according to Appendix 4 stops supplying hydrogen halide, fluorine, chlorine, chlorine trifluoride, or fluorine radicals to the vacuum pump when the thickness of the product film in the vacuum pump falls to or below the predetermined thickness. This means that this product removal apparatus can suppress corrosion of the vacuum pump due to over-etching.
Appendix 5
(64) In the product removal apparatus according to Appendix 5, in relation to the product removal apparatus of Appendix 4, the film thickness gauge is an optical film thickness gauge, and the optical film thickness gauge comprises an incident optical fiber for emitting light and a light-receiving fiber for receiving reflected light resulting from the light being reflected, and is configured to determine the film thickness from the reflected light received by the light-receiving fiber.
(65) The product removal apparatus according to Appendix 5 can measure the thickness of the product film in the vacuum pump by using light.
Appendix 6
(66) In the product removal apparatus according to Appendix 6, in relation to any one of the product removal apparatuses of Appendices 1 to 5, the sensor includes a vibration measuring instrument for measuring the vibration frequency of the vacuum pump, and the control device controls the gas supplier so that the supply of the gas to the vacuum pump is stopped when the vibration frequency measured by the vibration measuring instrument falls within a predetermined range.
(67) The product removal apparatus according to Appendix 6 stops supplying hydrogen halide, fluorine, chlorine, chlorine trifluoride, or fluorine radicals to the vacuum pump when the vibration frequency of the vacuum pump falls within a predetermined range. As described above, when the products are removed from the vacuum pump, the friction is eliminated and the vibration frequency of the vacuum pump reverts to its default value. As a result, the frequency of the vacuum pump falls within a predetermined range. Accordingly, in this product removal apparatus, when the amount of products decreases, hydrogen halide, fluorine, chlorine, chlorine trifluoride, or fluorine radicals are not supplied to the vacuum pump. In other words, this product removal apparatus can suppress corrosion of the vacuum pump due to over-etching.
Appendix 7
(68) In the product removal apparatus according to Appendix 7, in relation to any one of the product removal apparatuses of Appendices 1 to 6, the gas supplier includes a valve for adjusting the flow rate of the gas supplied to the vacuum pump, and the control device controls the valve to stop the supply of the gas to the vacuum pump.
(69) The product removal apparatus according to Appendix 7 can stop the supply of the gas to the vacuum pump by the controller controlling a valve.
Appendix 8
(70) In the product removal apparatus according to Appendix 8, in relation to any one of the product removal apparatuses of Appendices 1 to 7, the gas supplier includes a plasma source for generating the fluorine radicals.
(71) In the product removal apparatus according to Appendix 8, the plasma source can generate fluorine radicals.
Appendix 9
(72) In the product removal apparatus according to Appendix 9, in relation to the product removal apparatus of Appendix 8, the plasma source is configured to generate the fluorine radicals from nitrogen trifluoride, sulfur hexafluoride, or carbon tetrafluoride.
(73) In the product removal apparatus according to Appendix 9, the plasma source can generate fluorine radicals from nitrogen trifluoride, sulfur hexafluoride, or carbon tetrafluoride.

Appendix 10

(74) In the product removal apparatus according to Appendix 10, in relation to the product removal apparatus of Appendix 8 or 9, the gas supplier includes a reducer located downstream from the plasma source and configured to maintain the pressure inside the plasma source at 10 Torr or higher.

(75) If there is no pressure-controlling reducer between the vacuum pump and the plasma source, the pressure inside the plasma source will be lower when the vacuum pump intakes gas than with such a reducer. If the pressure inside the plasma source drops too much, there is a risk that the plasma source will not be able to generate plasma. The product removal apparatus according to Appendix 10 includes a reducer configured to maintain the pressure inside the plasma source at 10 Torr or higher. This allows the plasma source to stably generate plasma even while the vacuum pump is intaking gas.

Appendix 11

(76) In the product removal apparatus according to Appendix 11, in relation to any one of the product removal apparatuses of Appendices 8 to 10, the gas supplier is located downstream from the plasma source and comprises a pipe coated with aluminum oxide or insulator.

(77) According to the product removal apparatus according to Appendix 11, the pipe that carries fluorine radicals is coated with aluminum oxide or insulator. Consequently, the fluorine radicals are made less prone to deactivation than those flowing through a pipe that is not coated with aluminum oxide or insulator.

Appendix 12

(78) A treatment system according to Appendix 12 includes: a chamber; the vacuum pump; a pipe for connecting the chamber to the vacuum pump; and the product removal apparatus according to any one of Appendices 1 to 11, the apparatus being connected to the pipe.

(79) Similarly to the product removal apparatus according to Appendix 1, the treatment system according to Appendix 12 can sufficiently remove the products deposited inside the vacuum pump while suppressing corrosion due to over-etching of the vacuum pump.

Appendix 13

(80) The treatment system according to Appendix 13, in relation to the treatment system of Appendix 12, further includes a detoxification device located downstream from the vacuum pump.

(81) The treatment system according to Appendix 13 can use a detoxification device to detoxify the gas supplied from the vacuum pump to the detoxification device.

Appendix 14

(82) A product removal method according to Appendix 14 includes the steps of: supplying a gas containing hydrogen halide, fluorine, chlorine, chlorine trifluoride, or fluorine radicals to a vacuum pump; measuring the temperature inside the vacuum pump, the thickness of a film of a product in the flow path in the vacuum pump, or the vibration frequency of the vacuum pump; and stopping the supply of the gas to the vacuum pump depending on a rate of temperature increase calculated from the temperature, the film thickness, or the vibration frequency.

(83) Similarly to the product removal apparatus according to Appendix 1, the product removal method according to Appendix 14 can sufficiently remove the products deposited in the flow paths in the vacuum pump while suppressing corrosion of the vacuum pump due to over-etching.

(84) The embodiments of the present invention and the related modifications, which have been described above, are intended to facilitate understanding of the present invention, and needless to say, not intended to limit the present invention. The present invention may be modified and improved as appropriate without departing from its scope, and the equivalents are included in the present invention. Also, as long as at least some of the aforementioned problems can be solved or at least some of the aforementioned advantageous effects can be achieved, the components described in the claims and herein can be selectively used in combination or omitted.

REFERENCE SIGNS LIST

(85) **100**: Treatment system **110**: Semiconductor treatment apparatus **112**: Chamber **120**: Detoxification device **150**: Vacuum pump **160**: First vacuum pump **164**: Roots rotor **170**: Second vacuum pump **174**: Roots rotor **200**: Product removal apparatus **300**: Gas supplier **310**: Plasma source **320**: Reducer **330**: Valve **340**: Pipe **360**: Gas supplier **400**: Sensor **420***a*, **420***b*: Temperature sensor **422***a*, **422***b*: Temperature measuring section **440***a*, **440***b*: Optical film thickness gauge **442***a*, **442***b*: Incident optical fiber **444***a*, **444***b*: Light-receiving fibers **450**: Vibration measuring instrument **500**: Control device

Claims

1. A product removal apparatus comprising: a vacuum pump; a sensor for measuring the temperature of the inside of the vacuum pump, the thickness of a film of a product in a flow path in the vacuum pump, or the vibration frequency of the vacuum pump; a gas supplier for supplying a gas containing hydrogen halide, fluorine, chlorine, chlorine trifluoride, or fluorine radicals to the vacuum pump; and a control device, wherein the control device controls the gas supplier so that the supply of the gas to the vacuum pump is stopped depending on a rate of temperature increase calculated by the control device from the temperature measured by the sensor, the film thickness, or the vibration frequency, the sensor comprises a temperature sensor for measuring the temperature of the inside of the vacuum pump, and the control device calculates the rate of temperature increase from the temperature measured by the sensor, and controls the gas supplier so that the supply of the gas to the vacuum pump is stopped when the rate of temperature increase starts to decrease.
2. The product removal apparatus according to claim 1, wherein the temperature sensor comprises a temperature measuring section to be located downstream from a rotor of the vacuum pump.
3. The product removal apparatus according to claim 1, wherein the sensor includes a film thickness gauge for measuring the thickness of a film of a product in the flow path in the vacuum pump, and the control device controls the gas supplier so that the supply of the gas to the vacuum pump is stopped when the film thickness measured by the film thickness gauge falls to or below a predetermined thickness.
4. The product removal apparatus according to claim 3, wherein the film thickness gauge is an optical film thickness gauge, and the optical film thickness gauge comprises an incident optical fiber for emitting light and a light-receiving fiber for receiving reflected light resulting from the light being reflected, and is configured to determine the film thickness from the reflected light received by the light-receiving fiber.
5. The product removal apparatus according to claim 1, wherein the sensor comprises a vibration measuring instrument for measuring the vibration frequency of the vacuum pump, and the control device controls the gas supplier so that the supply of the gas to the vacuum pump is stopped when the vibration frequency measured by the vibration measuring instrument falls within a predetermined range.
6. The product removal apparatus according to claim 1, wherein the gas supplier comprises a valve for adjusting the flow rate of the gas supplied to the vacuum pump, and the control device controls the valve to stop the supply of the gas to the vacuum pump.
7. The product removal apparatus according to claim 1, wherein the gas supplier comprises a plasma source for generating the fluorine radicals.
8. The product removal apparatus according to claim 7, wherein the plasma source is configured to generate the fluorine radicals from nitrogen trifluoride, sulfur hexafluoride, or carbon tetrafluoride.
9. The product removal apparatus according to claim 7, wherein the gas supplier comprises a reducer located downstream from the plasma source and configured to maintain the pressure inside the plasma source at 10 Torr or higher.
10. The product removal apparatus according to any one of claim 7, wherein the gas supplier is located downstream from the plasma source and comprises a pipe coated with aluminum oxide or

insulator.

11. A treatment system comprising: the product removal apparatus according to claim 1; a chamber; a pipe for connecting the chamber to the vacuum pump; and the apparatus being connected to the pipe.

12. The treatment system according to claim 11, further comprising a detoxification device located downstream from the vacuum pump.

13. A product removal method comprising the steps of: providing the product removal apparatus of claim 1; supplying a gas containing hydrogen halide, fluorine, chlorine, chlorine trifluoride, or fluorine radicals to the vacuum pump; measuring the temperature inside the vacuum pump, the thickness of a film of a product in the flow path in the vacuum pump, or the vibration frequency of the vacuum pump; and stopping the supply of the gas to the vacuum pump depending on a rate of temperature increase calculated from the temperature, the film thickness, or the vibration frequency.