

Description

Title of the Invention: ULTRAPURE WATER PRODUCTION DEVICE AND ULTRAPURE WATER PRODUCTION METHOD

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Technical Field

[0001]

The present invention relates to an ultrapure water production apparatus and an ultrapure water production method.

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Background Art

[0002]

In recent years, as demands for the quality of ultrapure water have increased, methods for decomposing and removing trace amounts of organic matter contained in water, in particular, have been investigated. TOC (Total Organic Carbon) is used as an indicator of water quality after decomposition and removal of organic matter, and it is required that TOC be below a certain standard.

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[0003]

Ultraviolet oxidation treatment is one method for decomposing and removing trace amounts of organic matter in water. In ultraviolet oxidation treatment, OH radicals are generated by the oxidative decomposition of water, and the OH radicals can oxidatively decompose organic matter (TOC components).

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[0004]

However, in ultraviolet oxidation treatment, hydrogen peroxide is generated by the association of OH radicals (excess) generated by the decomposition of water. Hydrogen peroxide deteriorates resin materials such as ion exchange resins installed downstream of the ultraviolet oxidation device, leading to a decrease in the performance of the ultrapure water production device. Furthermore, deterioration of resin materials such as ion exchange resins causes generation of new organic matter derived from the resin, thereby causing a problem of a decrease in the quality of ultrapure water.

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[0005]

Therefore, a method for removing hydrogen peroxide from water has been proposed, in which a platinum-group metal supported catalyst—where a platinum-group metal such as palladium (Pd) or platinum (Pt) is supported on a carrier—is used. By using a platinum-group

metal supported catalyst, hydrogen peroxide can be decomposed and removed by the reaction represented by $2\text{H}_2\text{O}_2 \rightarrow 2\text{H}_2\text{O} + \text{O}_2$.

[0006]

As an example of a method and apparatus for producing ultrapure water using such a method for removing hydrogen peroxide, Patent Document 1 discloses a method and apparatus for producing ultrapure water in which the water to be treated is subjected to ultraviolet oxidation treatment in an ultraviolet oxidation device, and then hydrogen peroxide is removed using a hydrogen peroxide removal device that uses a specific platinum-based catalyst. More specifically, the document describes a method and apparatus for producing pure water characterized in that the platinum-based catalyst is a platinum-based metal colloidal particle supported on an anion exchange resin, the TOC of the feed water supplied to the ultraviolet oxidation device is 5 ppb or less, the inorganic carbonate ion concentration of the feed water supplied to the ultraviolet oxidation device is less than 1 ppb, and the inorganic carbonate ion concentration of the treated water from the ultraviolet oxidation device is 1 ppb or more, and the document states that they aim to provide a method and apparatus for producing pure water that can prevent (or suppress) deterioration of the catalyst resin and stably decompose hydrogen peroxide over a long period of time.

[0007]

Furthermore, Patent Document 2 discloses a method and apparatus for reducing hydrogen peroxide in the water to be treated by contacting the water containing hydrogen peroxide with a catalyst resin in which a platinum-group metal is supported on a strong base anion exchange resin.

Prior Art Documents

Patent documents

[0008]

Patent Document 1: JP 5854163 B2

Patent Document 2: JP 2010-069460 A

Summary of the Invention

Problem to be solved by the invention

[0009]

Patent Document 1 describes, as an effect of the invention, that by keeping the TOC of the feed water supplied to the ultraviolet oxidation device at 5 ppb or less, the organic acid

concentration is reduced, preventing poisoning (deterioration) of a platinum-based catalyst for removing hydrogen peroxide, which is installed downstream of the ultraviolet oxidation device, and extending the catalyst's life. It also describes that by setting the ultraviolet oxidation treatment conditions so that the inorganic carbonate ion concentrations of the feed water supplied to and effluent water from the ultraviolet oxidation device are each within a specific range, the proportion of organic matter that is decomposed to CO₂ increases (i.e., the organic matter concentration decreases).

[0010]

However, the method described in Patent Document 1 requires that the inorganic carbonate ion concentration of the treated water from the ultraviolet oxidation device be equal to or greater than a predetermined level, and there is room for further extension of the catalyst life. Specifically, the inventors discovered that inorganic carbonate ions contribute to the deterioration of a platinum-based catalyst-supported resin, and that as the inorganic carbonate ion concentration increases, the platinum-based catalyst-supported resin deteriorates, resulting in a decrease in the quality of the obtained ultrapure water. More specifically, they discovered that in ultraviolet oxidation treatment, organic matter (TOC components) is oxidatively decomposed to produce organic acids, which are further oxidatively decomposed to produce CO₂, which dissolves in the treated water and becomes inorganic carbonate ions, resulting in an increase in the inorganic carbonate ion concentration in the treated water and deterioration of the platinum-based catalyst-supported resin.

[0011]

The object of the present invention is to solve the problem arising from the above circumstances, namely to provide an ultrapure water production apparatus and an ultrapure water production method capable of stably supplying ultrapure water having good quality over a long period of time.

Means for Solving the Problem

[0012]

The present invention includes the following aspects.

[1]

An ultrapure water production apparatus comprising:

a primary pure water production apparatus and a secondary pure water production apparatus,

wherein the primary pure water production apparatus comprises a first ultraviolet oxidation device,

the secondary pure water production apparatus comprises a second ultraviolet oxidation device and a hydrogen peroxide removal device provided downstream of the second ultraviolet oxidation device,

the hydrogen peroxide removal device comprises an ion-exchange material supporting
5 a platinum-group metal catalyst, and

the ultraviolet irradiation dose of the second ultraviolet oxidation device is controlled such that a difference ΔTOC ($\text{TOC}_{\text{SUP}} - \text{TOC}_{\text{TRE}}$) between a TOC value (TOC_{SUP}) of feed water to be supplied to the second ultraviolet oxidation device and a TOC value (TOC_{TRE}) of water treated by the second ultraviolet oxidation device is 1 ppb or less.

10 [2] The ultrapure water production apparatus according to [1], wherein the ultraviolet radiation dose of the first ultraviolet oxidation device is controlled such that the TOC value (TOC_{SUP}) of feed water to be supplied to the second ultraviolet oxidation device satisfies $0 < \text{TOC}_{\text{SUP}} \leq 5$ ppb.

[3] The ultrapure water production apparatus according to [1] or [2], wherein the ultraviolet
15 irradiation dose of the first ultraviolet oxidation device is greater than the ultraviolet irradiation dose of the second ultraviolet oxidation device.

[4] The ultrapure water production apparatus according to any one of [1] to [3], wherein the ultraviolet irradiation dose of the first ultraviolet oxidation device and the ultraviolet irradiation dose of the second ultraviolet oxidation device are controlled such that the TOC value (TOC_{TRE})
20 of water treated by the second ultraviolet oxidation device is 1 ppb or less.

[5] The ultrapure water production apparatus according to any one of [1] to [4] comprises a water quality meter upstream of and/or downstream of the second ultraviolet oxidation device, including further downstream thereof.

[6] The ultrapure water production apparatus according to any one of [1] to [5] comprises
25 a first TOC meter provided upstream of the second ultraviolet oxidation device and a second TOC meter provided downstream of the second ultraviolet oxidation device, including further downstream thereof.

[7] A method for producing ultrapure water using an ultrapure water production apparatus comprising a primary pure water production apparatus and a secondary pure water production
30 apparatus,

wherein the primary pure water production apparatus comprises a first ultraviolet oxidation device,

the secondary pure water production apparatus comprises a second ultraviolet oxidation device and a hydrogen peroxide removal device provided downstream of the second ultraviolet

oxidation device,

the hydrogen peroxide removal device comprises an ion-exchange material supporting a platinum-group metal catalyst, and

the method comprises adjusting the ultraviolet irradiation dose of the second ultraviolet oxidation device such that a difference ΔTOC ($\text{TOC}_{\text{SUP}} - \text{TOC}_{\text{TRE}}$) between a TOC value (TOC_{SUP}) of feed water to be supplied to the second ultraviolet oxidation device and a TOC value (TOC_{TRE}) of water treated by the second ultraviolet oxidation device is 1 ppb or less.

[8] The method for producing ultrapure water according to [7], wherein the ultraviolet irradiation dose of the first ultraviolet oxidation device is adjusted such that the TOC value (TOC_{SUP}) of feed water to be supplied to the second ultraviolet oxidation device satisfies $0 < \text{TOC}_{\text{SUP}} \leq 5$ ppb.

[9] The method for producing ultrapure water according to [7] or [8], wherein the ultraviolet irradiation dose of the first ultraviolet oxidation device is adjusted to be greater than the ultraviolet irradiation dose of the second ultraviolet oxidation device.

[10] The method for producing ultrapure water according to any one of [7] to [9], wherein the ultraviolet irradiation dose of the first ultraviolet oxidation device and the ultraviolet irradiation dose of the second ultraviolet oxidation device are adjusted such that the TOC value (TOC_{TRE}) of water treated by the second ultraviolet oxidation device is 1 ppb or less.

[11] The method for producing ultrapure water according to any one of [7] to [10], wherein the ultrapure water production apparatus comprises a water quality meter provided upstream of and/or downstream of the second ultraviolet oxidation device, including further downstream thereof.

[12] The method for producing ultrapure water according to any one of [7] to [11], wherein the ultrapure water production apparatus comprises a first TOC meter provided upstream of the second ultraviolet oxidation device and a second TOC meter provided downstream of the second ultraviolet oxidation device, including further downstream thereof.

Effects of the Invention

[0013]

According to the present invention, it is possible to provide an ultrapure water production apparatus and an ultrapure water production method capable of stably supplying ultrapure water having good quality over a long period of time.

Brief Description of the Drawings

[0014]

[FIG. 1] FIG. 1 is a schematic diagram of an example of an ultrapure water production apparatus according to one embodiment of the present invention.

[FIG. 2] FIG. 2 is a graph showing a correlation between an OH-type proportion of catalytic resin in a hydrogen peroxide removal device and hydrogen peroxide removal performance.

[FIG. 3] FIG. 3 is a schematic diagram of an ion exchange resin container packed with catalytic resin and used in Test Example 1 (hydrogen peroxide removal device).

Modes for Carrying Out the Invention

[0015]

Preferred embodiments of the present invention will now be described.

[0016]

An ultrapure water production apparatus according to one embodiment of the present invention comprises a primary pure water production apparatus (Make-up) and a secondary pure water production apparatus (Polishing), which is supplied with the water treated by the primary pure water production apparatus.

The primary pure water production apparatus comprises a first ultraviolet oxidation device, and the secondary pure water production apparatus comprises a second ultraviolet oxidation device and a hydrogen peroxide removal device located downstream of the second ultraviolet oxidation device.

The first and second ultraviolet oxidation devices decompose and remove trace amounts of organic matter (TOC components) in water through ultraviolet oxidation treatment. In this ultraviolet oxidation treatment, water is oxidatively decomposed to generate OH radicals, which then oxidatively decompose the organic matter (TOC components). During this process, the generated organic acids are further oxidatively decomposed to produce CO₂, which forms inorganic carbonate ions in the treated water, while hydrogen peroxide is generated by the association of excess OH radicals.

The hydrogen peroxide removal device is a catalytic device that comprises an ion-exchange material supporting a platinum-group metal catalyst (hereinafter referred to as a "catalyst-loaded support" as appropriate) and decomposes and removes hydrogen peroxide. This hydrogen peroxide removal device (hereinafter referred to as a "catalytic device" as appropriate) is a device that decomposes and removes hydrogen peroxide generated by ultraviolet oxidation treatment through the action of a catalyst.

[0017]

In the ultrapure water production apparatus according to this embodiment, the ultraviolet radiation dose of the second ultraviolet oxidation device is controlled such that a difference ΔTOC ($\text{TOC}_{\text{SUP}} - \text{TOC}_{\text{TRE}}$) between a TOC value (TOC_{SUP}) of the feed water to be supplied to the second ultraviolet oxidation device and a TOC value (TOC_{TRE}) of the water treated by the second ultraviolet oxidation device is 1 ppb or less.

Here, "control" includes both automatic and manual control.

Furthermore, the feed water to be supplied to the second ultraviolet oxidation device contains TOC components ($\text{TOC}_{\text{SUP}} \neq 0$), and the relationship between TOC_{SUP} of the feed water to be supplied and TOC_{TRE} of the treated water is $\text{TOC}_{\text{SUP}} > \text{TOC}_{\text{TRE}}$ (i.e., $0 < \Delta\text{TOC}$).

An ultrapure water production method according to another embodiment of the present invention is a method for producing ultrapure water using such an ultrapure water production apparatus, in which the ultraviolet irradiation dose of the second ultraviolet oxidation device is adjusted such that a difference ΔTOC ($\text{TOC}_{\text{SUP}} - \text{TOC}_{\text{TRE}}$) between a TOC value (TOC_{SUP}) of feed water to be supplied to the second ultraviolet oxidation device and a TOC value (TOC_{TRE}) of water treated by the second ultraviolet oxidation device is 1 ppb or less.

Here, "adjust" includes both automatic and manual adjustment.

As described above, the feed water to be supplied to the second ultraviolet oxidation device contains TOC components ($\text{TOC}_{\text{SUP}} \neq 0$), and the relationship between TOC_{SUP} of the feed water to be supplied and TOC_{TRE} of the treated water is $\text{TOC}_{\text{SUP}} > \text{TOC}_{\text{TRE}}$ (i.e., $0 < \Delta\text{TOC}$).

[0018]

As described above, by controlling or adjusting such that the difference ΔTOC ($\text{TOC}_{\text{SUP}} - \text{TOC}_{\text{TRE}}$) between the TOC value (TOC_{SUP}) of the feed water to be supplied to the second ultraviolet oxidation device and the TOC value (TOC_{TRE}) of the water treated by the second ultraviolet oxidation device is 1 ppb or less, the inorganic carbonate ion concentration in effluent water from the second ultraviolet oxidation device can be maintained at or below a predetermined level. As a result, deterioration of a catalyst-loaded support in the downstream hydrogen peroxide removal device caused by inorganic carbonate ions can be suppressed, thereby enabling a stable supply of high purity ultrapure water ((i.e., operating the apparatus so that fluctuations in water quality are minimized).

In the present invention, it is necessary to control or adjust the ultraviolet light irradiation dose such that ΔTOC is 1 ppb or less, preferably 0.5 ppb or less, and more preferably at less than 0.2 ppb.

Moreover, assuming that all 1 ppb of TOC components are decomposed, a TOC value of 1 ppb corresponds to an inorganic carbonate ion concentration of 5 ppb under the following

conditions:

If all the organic components (TOC components) in the water are decomposed, they are ultimately converted into water and carbon dioxide ($C_xH_yO_z \rightarrow CO_2 + H_2O$). The carbon dioxide produced dissolves in the water to form inorganic carbonate ions (HCO_3^- , CO_3^{2-}). Under the assumption that all the produced carbon dioxide dissolves in the water, and is fully converted into inorganic carbonate ions, the mass ratio of carbon (C) in the organic components (TOC components) to the resulting inorganic carbonate ions is approximately 1:5, as shown below.

$$[\text{TOC component (C)}] : [\text{Inorganic carbonate ion (HCO}_3^-)] = 12 : (1 + 12 + 16 \times 3) \approx 1 : 5$$

$$[\text{TOC component (C)}] : [\text{Inorganic carbonate ion (CO}_3^{2-})] = 12 : (12 + 16 \times 3) = 1 : 5$$

[0019]

When the difference ΔTOC ($\text{TOC}_{\text{SUP}} - \text{TOC}_{\text{TRE}}$) between the TOC value (TOC_{SUP}) of feed water to be supplied to the second ultraviolet oxidation device and the TOC value (TOC_{TRE}) of the water treated by the second ultraviolet oxidation device is 1 ppb or less, it is preferable to perform ultraviolet oxidation treatment on water to be treated by the first ultraviolet oxidation device at a sufficiently high irradiation dose, thereby sufficiently reducing the TOC value (TOC_{SUP}) of feed water to be supplied to the second ultraviolet oxidation device in the subsequent stage.

In such a case, it is preferable that the ultraviolet irradiation dose of the first ultraviolet oxidation device be greater than the ultraviolet irradiation dose of the second ultraviolet oxidation device.

Conventionally, in order to reduce the TOC value of the final treated water, the ultraviolet irradiation dose of the ultraviolet oxidation device (second ultraviolet oxidation device) in the downstream secondary pure water production apparatus is increased so as to sufficiently decompose TOC components. However, when a large amount of TOC components is decomposed in this process, a large amount of inorganic carbonate ions is generated. As a result, problems caused by inorganic carbonate ions (deterioration of the catalyst-loaded support in the hydrogen peroxide removal device) are more likely to occur.

Therefore, in the present invention, it is preferable to increase the ultraviolet irradiation dose of the ultraviolet oxidation device (first ultraviolet oxidation device) in the upstream primary pure water production apparatus to sufficiently reduce the TOC value in advance, thereby reducing the amount of TOC components required for decomposition in the ultraviolet oxidation device (second ultraviolet oxidation device) in the downstream secondary pure water production apparatus. This makes it possible to suppress the amount of inorganic carbonate ions generated in the downstream secondary pure water production apparatus and, as a result, to suppress

deterioration of the catalyst-loaded support in the hydrogen peroxide removal device caused by inorganic carbonate ions.

[0020]

In the ultrapure water production apparatus and production method of the present invention, from the viewpoint of more sufficiently reducing the amount of TOC components to be oxidatively decomposed by the second ultraviolet oxidation device, it is preferable that the ultraviolet irradiation dose of the first ultraviolet oxidation device be controlled (or adjusted) such that the TOC value (TOC_{SUP}) of feed water to be supplied to the second ultraviolet oxidation device is 5 ppb or less ($0 < \text{TOC}_{\text{SUP}} \leq 5 \text{ ppb}$), preferably 3 ppb or less ($0 < \text{TOC}_{\text{SUP}} \leq 3 \text{ ppb}$).

In addition to sufficiently reducing the TOC of the final treated water, from the viewpoint of further sufficiently reducing the amount of TOC components to be oxidatively decomposed by the second ultraviolet oxidation device, it is preferable that the ultraviolet irradiation dose of the first ultraviolet oxidation device and the ultraviolet irradiation dose of the second ultraviolet oxidation device be controlled (or adjusted) such that the TOC value (TOC_{TRE}) of the water treated by the second ultraviolet oxidation device is 1 ppb or less.

In addition, even if TOC is excessively reduced in the primary pure water production apparatus, organic matter may be mixed into the treated water, thereby increasing the TOC content. Since such an increase can be removed in the secondary pure water production apparatus, it is not necessary to excessively reduce TOC in the primary pure water production apparatus. From the viewpoint of treatment efficiency, it is preferable to reduce TOC appropriately depending on the TOC content of water to be treated. To suppress excessive ultraviolet irradiation in the first ultraviolet oxidation device, the ultraviolet irradiation dose of the first ultraviolet oxidation device is preferably controlled or adjusted within an ultraviolet irradiation dose range in which the TOC value (TOC_{SUP}) of feed water to be supplied to the second ultraviolet oxidation device is 0.3 ppb or more (a dose range in which it is not reduced to less than 0.3 ppb), more preferably within an ultraviolet irradiation dose range in which the TOC value is 0.5 ppb or more (a dose range in which it is not reduced to less than 0.5 ppb), or may be controlled or adjusted within an ultraviolet irradiation dose range in which the TOC value is 1 ppb or more (a dose range in which it is not reduced to less than 1 ppb).

[0021]

TOC can be measured by providing a TOC meter between the first ultraviolet oxidation device and the second ultraviolet oxidation device, and another TOC meter downstream of the second ultraviolet oxidation device, including further downstream thereof. Accordingly, the TOC of the treated water between the first ultraviolet oxidation device and the second ultraviolet

oxidation device and the TOC of the treated water downstream of the second ultraviolet oxidation device, including further downstream thereof, can be measured.

Alternatively, a single TOC meter may be provided at either one of a position between the first ultraviolet oxidation device and the second ultraviolet oxidation device, or a position downstream of the second ultraviolet oxidation device, including further downstream thereof, so that both the TOC of the treated water between the first ultraviolet oxidation device and the second ultraviolet oxidation device and the TOC of the treated water downstream of the second ultraviolet oxidation device, including further downstream thereof, can be measured. Accordingly, the TOC of both treated waters can be measured with a single TOC meter.

[0022]

Thus, in the ultrapure water production apparatus and ultrapure water production method of the present invention, the TOC of the treated water between the first ultraviolet oxidation device and the second ultraviolet oxidation device and the TOC of the treated water downstream of the second ultraviolet oxidation device, including further downstream thereof, can be measured by one or two TOC meters.

With regard to measurement of the TOC of the treated water between the first ultraviolet oxidation device and the second ultraviolet oxidation device, it is preferable, in order to obtain a more accurate measurement value (TOC_{SUP}), to measure the water immediately before being supplied to the second ultraviolet oxidation device (i.e., the treated water between the second ultraviolet oxidation device and a treatment device disposed immediately upstream thereof).

On the other hand, the location at which the TOC of the treated water downstream of the second ultraviolet oxidation device is measured, including locations further downstream thereof, is not particularly limited, provided that it is located downstream of the second ultraviolet oxidation device, including locations further downstream thereof, as described below. However, from the viewpoint of simplifying the equipment, it is preferable to measure the TOC of treated water discharged from the final treatment device of the secondary pure water production apparatus. This makes it possible to simultaneously obtain the TOC value (TOC_{TRE}) for calculating ΔTOC and the TOC value of the final treated water produced by the ultrapure water production apparatus.

[0023]

The TOC meter provided in this manner can measure the TOC of the treated water between the first ultraviolet oxidation device and the second ultraviolet oxidation device and the TOC of the treated water downstream of the second ultraviolet oxidation device, including further downstream thereof; and based on these TOC measurements, the ultraviolet irradiation doses of the first and second ultraviolet oxidation devices can be controlled (or adjusted).

For example, the ultraviolet irradiation doses of the first and second ultraviolet oxidation devices can be controlled (or adjusted) such that the difference (ΔTOC) between the measured TOC value of the effluent water from the first ultraviolet oxidation device as the first TOC value (TOC_{SUP}) and the measured TOC value of the effluent water from the second ultraviolet oxidation device as the second TOC value (TOC_{TRE}) is 1 ppb or less.

In this case, by performing ultraviolet oxidation treatment in the first ultraviolet oxidation device with a sufficiently high irradiation dose such that the first TOC value becomes a predetermined value or less (for example, 5 ppb or less), the amount of organic matter in feed water to be supplied to the downstream second ultraviolet oxidation device can be sufficiently reduced. Further, the ultraviolet irradiation doses of the first and second ultraviolet oxidation devices can be controlled (or adjusted) such that the second TOC value becomes a predetermined value or less (e.g., 1 ppb or less).

[0024]

The TOC meter can be a normal TOC meter used in the production of ultrapure water. For example, a complete oxidation type TOC meter can be used, in which a portion of the treated water is introduced into a measurement cell, the valve is closed, ultraviolet light is applied, and the difference between the conductivity after complete oxidation, when the conductivity has become constant, and the conductivity before ultraviolet light irradiation can be converted into a TOC value.

[0025]

In the ultrapure water production apparatus of the present invention, various water quality meters in addition to a TOC meter can be provided at desired locations. Based on measurements obtained from the water quality meters, water quality can be managed, and the various processing devices constituting the ultrapure water production apparatus can be controlled or adjusted.

For example, electrical conductivity can be measured using a water quality meter, and the ultraviolet irradiation dose in the first ultraviolet oxidation device and/or the ultraviolet irradiation dose in the second ultraviolet oxidation device can be controlled based on the measured value. In this case, the water quality meter may be provided between the first ultraviolet oxidation device and the second ultraviolet oxidation device and downstream of the second ultraviolet oxidation device, including further downstream thereof, or may be provided at either one of these locations. A single water quality meter may also be used to measure both the quality of the treated water between the first ultraviolet oxidation device and the second ultraviolet oxidation device and the quality of the treated water downstream of the second ultraviolet oxidation device, including further downstream thereof.

[0026]

The configuration of the ultrapure water production apparatus of the present invention will be further described below.

FIG. 1 shows an example of the configuration of an ultrapure water production apparatus according to one embodiment of the present invention; however, the present invention is not limited to this configuration.

As shown in FIG. 1, the ultrapure water production apparatus comprises a primary pure water production apparatus 1 and a secondary pure water production apparatus 2, in that order. The primary pure water production apparatus 1 comprises a first ultraviolet oxidation device 11, an ion exchange device 12, a boron selective resin device 13, and a degassing device 14, in that order. The secondary pure water production apparatus 2 comprises a second ultraviolet oxidation device 21, a hydrogen peroxide removal device (catalytic device) 22, a degassing device 23, an ion exchange device 24, and an ultrafiltration membrane device 25, in that order.

[0027]

As described above, the TOC meter may be provided between the first ultraviolet oxidation device 11 and the second ultraviolet oxidation device 21, and/or downstream of the second ultraviolet oxidation device 21, including further downstream thereof. In the ultrapure water production apparatus shown in FIG. 1, a TOC meter 31 is provided upstream of the second ultraviolet oxidation device 21, and a TOC meter 32 is provided downstream of the final treatment device of the secondary pure water production apparatus 2.

In the measurement of TOC, the first TOC value (TOC_{SUP}) may be a measured value of feed water to be supplied to the second ultraviolet oxidation device 21, and the second TOC value (TOC_{TRE}) may be a measured value of water treated by the second ultraviolet oxidation device 21 (a measured value of effluent water from the second ultraviolet oxidation device 21 or a measured value of effluent water from each treatment device provided downstream of the second ultraviolet oxidation device, including further downstream thereof). The difference between the first TOC value and the second TOC value is defined as ΔTOC , and the ultraviolet irradiation doses of the first and second ultraviolet oxidation devices may be controlled or adjusted such that ΔTOC is 1 ppb or less.

[0028]

The location of the downstream TOC meter is not particularly limited, provided that it is located downstream of the second ultraviolet oxidation device 21, including locations further downstream thereof; however, from the viewpoint of simplifying the equipment, it is preferable that the TOC meter 32 be disposed downstream of the final treatment device of the secondary pure

water production apparatus 2, as shown in FIG. 1. This makes it possible to measure the TOC value of the final treated water from the ultrapure water production apparatus, and this measured value may be used as the second TOC value (TOC_{TRE}) for calculating ΔTOC .

Furthermore, since the amount of TOC leached from the processing devices and equipment within the secondary pure water production apparatus 2 is small downstream of the second ultraviolet oxidation device 21, including further downstream thereof, the effect of the position of the TOC meter on ΔTOC can be ignored.

In the configuration shown in FIG. 1, two TOC meters are provided, but TOC meter 31 on the upstream side may be omitted and only TOC meter 32 on the downstream side may be used, and the downstream TOC meter 32 may be configured to receive a portion of feed water to be supplied to the second ultraviolet oxidation device 21. This allows a single TOC meter to measure both the TOC of feed water to be supplied to the second ultraviolet oxidation device 21 and the TOC of the water treated by the second ultraviolet oxidation device 21.

[0029]

Although the configuration shown in FIG. 1 does not include a pretreatment device (pretreatment system), it may be provided as part of the configuration of the ultrapure water production apparatus as needed, or treated water that has been pretreated in the pretreatment device (pretreatment system) may be supplied to the primary pure water production apparatus of the ultrapure water production apparatus. In the pretreatment device (pretreatment system), pretreatment such as coagulation, pressure flotation, and filtration may be performed.

[0030]

(Primary pure water production apparatus)

The primary pure water production apparatus of the ultrapure water production apparatus of this embodiment includes a first ultraviolet oxidation device, and may further include treatment devices commonly used in ultrapure water production apparatuses, such as an ion exchange device (e.g., a regenerative ion exchange device), a boron-selective resin device, a degassing device (e.g., a membrane degassing device), and a reverse osmosis membrane device (RO device), as appropriate.

For example, as shown in FIG. 1 above, the primary pure water production apparatus 1 may have a configuration in which a first ultraviolet oxidation device 11, an ion exchange device 12 (e.g., a regenerative ion exchange resin), a boron selective resin device 13, and a degassing device 14 (e.g., a membrane degassing device) are connected in this order.

In the first ultraviolet oxidation device 11, organic matter is oxidatively decomposed; in the ion exchange device 12, impurity ions in the water are removed; in the boron selective resin

device 13, boron in the water is removed; and in the degassing device 14, gases such as dissolved oxygen in the water are removed. The boron selective resin device 13 may be omitted as necessary. A reverse osmosis membrane device may also be provided to remove inorganic matter, organic matter, fine particles, microorganisms, and the like from the water.

5 [0031]

(Secondary pure water production apparatus)

The secondary pure water production apparatus of the ultrapure water production apparatus of this embodiment includes a second ultraviolet oxidation device and a hydrogen peroxide removal device (catalytic device) disposed downstream thereof, and may further include
10 treatment devices commonly used in ultrapure water production apparatuses, such as a degassing device (e.g., a membrane degassing device), an ion exchange device (e.g., a non-regenerative ion exchange device such as a cartridge polisher), and an ultrafiltration membrane device (UF), as appropriate.

For example, as shown in FIG. 1 above, the secondary pure water production apparatus
15 2 may have a configuration in which a second ultraviolet oxidation device 21, a hydrogen peroxide removal device 22, a degassing device 23 (e.g., a membrane degassing device), an ion exchange device 24 (e.g., a non-regenerative ion exchange device), and an ultrafiltration membrane device 25 are connected in this order. If necessary, the arrangement order of the degassing device 23 and the ion exchange device 24 may be reversed. Furthermore, a tank for temporarily storing treated
20 water from the primary pure water production apparatus 1 may be provided upstream of the secondary pure water production apparatus 2.

In the second ultraviolet oxidation device 21, organic matter is oxidatively decomposed; in the hydrogen peroxide removal device 22, hydrogen peroxide generated by the upstream second ultraviolet oxidation device 21 is decomposed; in the degassing device 23, gases
25 such as dissolved oxygen in the water are removed; in the ion exchange device 24, impurity ions in the water are removed; and in the ultrafiltration membrane device 25, fine particles generated from ion exchange resins and the like are removed.

Downstream of the hydrogen peroxide removal device 22 and further downstream thereof, any of the above-described devices may be omitted as necessary; however, it is preferable
30 that at least one of the degassing device (e.g., a membrane degassing device) 23 and the ion exchange device 24 (e.g., a non-regenerative ion exchange device) be provided, and that at least one of a degassing treatment and an ion exchange treatment be performed on water treated by the hydrogen peroxide removal device.

[0032]

(Hydrogen peroxide removal device (catalytic device))

The hydrogen peroxide removal device provided in the secondary pure water production apparatus is a catalytic device for decomposing the hydrogen peroxide generated in the upstream ultraviolet oxidation device, and includes an ion-exchange material (catalyst-loaded support) supporting a platinum-group metal catalyst.

Examples of platinum-group metal catalysts include catalytic metals such as ruthenium, rhodium, palladium, osmium, iridium, and platinum, and one type may be used alone, or two or more types may be combined, and two or more types may also be used as an alloy. Among these catalytic metals, platinum, palladium, and alloys of platinum and palladium are preferred, and these may be used alone or in combination with two or more types. Palladium is particularly preferred because it exhibits excellent catalytic activity and is relatively inexpensive to obtain.

Examples of supports for platinum-group metal catalysts include metal oxides such as magnesia, titania, alumina, silica-alumina, and zirconia, activated carbon, zeolite, diatomaceous earth, and ion-exchange materials (such as ion exchange resins or monolithic organic porous anion-exchange materials), and among these, it is preferable to use an ion-exchange material. As the ion-exchange material, ion exchange resins are preferred, and the ion-exchange material supporting a platinum-group metal catalyst according to the embodiments of the present invention is preferably an ion exchange resin supporting a platinum-group metal catalyst (hereinafter appropriately referred to as a catalytic resin). As for the type of the ion-exchange material, anion-exchange materials are preferred, and among them, anion exchange resins are preferred, and strong basic anion exchange resins are particularly preferred. There are no particular restrictions on the shape of supports for platinum-group metal catalysts, and both granular and pellet-shaped forms may be used. When using an ion exchange resin such as an anion exchange resin as a support for platinum-group metal catalysts, a gel-like resin (gel-type resin) may be used.

When water to be treated containing hydrogen peroxide is brought into contact with such a catalyst-loaded support, the hydrogen peroxide in water to be treated is decomposed according to the reaction: $2\text{H}_2\text{O}_2 \rightarrow 2\text{H}_2\text{O} + \text{O}_2$.

[0033]

As the ion-exchange material (catalyst-loaded support) supporting such a platinum-group metal catalyst, for example, the catalyst resin disclosed in JP 2010-069460 A can be suitably used.

Specifically, a catalytic resin that is a strong base anion exchange resin supporting a platinum-group metal catalyst, in which 70% or more, preferably 90% or more, and more preferably 95% or more of the total exchange capacity of the strong base anion exchange resin is

of the OH type, is preferably used.

The amount of the platinum-group metal catalyst (catalytic metal) supported on the strong base anion exchange resin is in the range of 10 mg-catalyst/L-R to 500 mg-catalyst/L-R, preferably 10 mg-catalyst/L-R to 170 mg-catalyst/L-R, and more preferably 10 mg-catalyst/L-R to 50 mg-catalyst/L-R. Here, R denotes an anion exchange resin in the OH type, and "mg-catalyst/L-R" means the mass (mg) of the catalyst per 1 L of the anion exchange resin in the OH type.

From the viewpoint of hydrogen peroxide decomposition efficiency, the strong base anion exchange resin is preferably of a gel type.

Furthermore, the catalytic resin may be one obtained by passing an ionic solution of a platinum-group metal through the strong base anion exchange resin, followed by passing a reducing agent such as formalin, thereby supporting the platinum-group metal catalyst (catalytic metal) on the strong base anion exchange resin.

Water to be treated is preferably brought into contact with the catalytic resin at a space velocity for water flow (SV) in the range of 30 to 2000 hr⁻¹, more preferably in the range of 200 to 2000 hr⁻¹.

A hydrogen supply device may be provided in the hydrogen peroxide removal device to supply hydrogen into water to be treated. This allows the decomposition of hydrogen peroxide in water to be treated, and also facilitates the removal, by degassing, of gaseous components such as oxygen generated by the decomposition of hydrogen peroxide.

[0034]

(Ultraviolet oxidation device)

The first ultraviolet oxidation device and the second ultraviolet oxidation device used in the present invention may be ultraviolet oxidation devices commonly used in an ultrapure water production apparatus.

The ultraviolet oxidation device includes an ultraviolet lamp configured to irradiate ultraviolet light having a wavelength of approximately 100 to 200 nm onto the water to be treated, and is not particularly limited provided that it is capable of oxidatively decomposing organic matter in the water to be treated.

From the viewpoint of decomposing organic matter in the water to be treated, the ultraviolet oxidation device preferably includes an ultraviolet lamp configured to irradiate ultraviolet light having a wavelength of approximately 185 nm. The ultraviolet lamp is not particularly limited, and a low-pressure mercury lamp is preferred. Ultraviolet oxidation devices include flow-through types and immersion types, and flow-through types are preferred from the

viewpoint of treatment efficiency.

[0035]

The first and the second ultraviolet oxidation devices are configured so that the ultraviolet irradiation dose can be controlled (or adjusted) in accordance with the first TOC value (TOC_{SUP}) and the second TOC value (TOC_{TRE}), which are the measured values described above.

An ultrapure water production apparatus according to an embodiment of the present invention may include an ultraviolet irradiation dose control device associated with the second ultraviolet oxidation device, and the ultraviolet irradiation dose control device is configured to control (or adjust) the ultraviolet irradiation dose of the second ultraviolet oxidation device based on an input TOC value. Specifically, the ultraviolet irradiation dose control device is configured to receive the first TOC value (TOC_{SUP}) and the second TOC value (TOC_{TRE}), and to control (or adjust) the ultraviolet irradiation dose of the second ultraviolet oxidation device such that the difference ΔTOC (TOC_{SUP} - TOC_{TRE}) is 1 ppb or less. The ultraviolet irradiation dose control device may also be configured to control (or adjust) the ultraviolet irradiation dose of the first ultraviolet oxidation device.

When the first TOC value (TOC_{SUP}) increases, simply increasing the ultraviolet irradiation dose of the second ultraviolet oxidation device to reduce the TOC of the ultrapure water obtained from the ultrapure water production apparatus may cause ΔTOC to exceed 1 ppb; therefore it is necessary to control (or adjust) the ultraviolet irradiation dose of the second ultraviolet oxidation device such that ΔTOC is maintained at 1 ppb or less. In this case, the ultraviolet irradiation dose of the second ultraviolet oxidation device may be controlled (or adjusted) while the ultraviolet irradiation dose of the first ultraviolet oxidation device may be increased to reduce the first TOC value (TOC_{SUP}).

[0036]

The ultraviolet irradiation dose control device may be configured to control (or adjust) the ultraviolet irradiation dose of the first ultraviolet oxidation device such that the first TOC value (TOC_{SUP}) is equal to or less than a predetermined value (e.g., 5 ppb or less). A separate ultraviolet irradiation dose control device may be provided in association with the first ultraviolet oxidation device, and this control device may be configured to control (or adjust) the ultraviolet irradiation dose of the first ultraviolet oxidation device such that the input first TOC value (TOC_{SUP}) is equal to or less than a predetermined value (e.g., 5 ppb or less). With these configurations, when the first TOC value (TOC_{SUP}) increases and is about to exceed the predetermined value (e.g., 5 ppb), the ultraviolet irradiation dose of the first ultraviolet oxidation device can be increased to control (or adjust) the first TOC value (TOC_{SUP}) to be equal to or less than the predetermined value (e.g., 5

ppb or less).

[0037]

The ultraviolet irradiation dose control device may be configured to control (or adjust) the ultraviolet irradiation dose of the first and/or second ultraviolet oxidation device such that the second TOC value (TOC_{TRE}) is equal to or less than a predetermined value (e.g., 1 ppb or less). With this configuration, when the second TOC value (TOC_{TRE}) increases and is about to exceed the predetermined value (e.g., 1 ppb), the ultraviolet irradiation dose of the first ultraviolet oxidation device and/or the second ultraviolet oxidation device can be increased to control (or adjust) the second TOC value (TOC_{TRE}) to be equal to or less than the predetermined value (e.g., 1 ppb or less). However, as described above, the ultraviolet irradiation dose of the second ultraviolet oxidation device is controlled (or adjusted) such that ΔTOC is maintained at 1 ppb or less.

[0038]

Methods for controlling the ultraviolet irradiation dose of the ultraviolet oxidation device using the ultraviolet irradiation dose control device include, for example, a method in which the ultraviolet irradiation dose control device controls the number of turned-on ultraviolet lamps provided in the ultraviolet oxidation device, a method in which the ultraviolet irradiation dose control device controls the lighting positions of the multiple ultraviolet lamps provided in the ultraviolet oxidation device (i.e., which ultraviolet lamp among the multiple ultraviolet lamps is turned on or off), a method in which the ultraviolet irradiation dose control device controls the value of the current passed through the multiple ultraviolet lamps provided in the ultraviolet oxidation device, and the like. In addition to these methods, known methods for controlling the ultraviolet irradiation dose can be adopted as appropriate.

[0039]

The majority of OH radicals generated by decomposition of water under ultraviolet irradiation in the ultraviolet oxidation device are used to decompose organic matter, but excess OH radicals combine to form hydrogen peroxide. This hydrogen peroxide is decomposed and removed in the hydrogen peroxide removal device (catalytic device) located downstream. Meanwhile, the ultraviolet oxidation device oxidatively decomposes the organic matter (TOC components) contained in the water to be treated into organic acids and further into CO_2 , forming carbonic acid in the water. As a result, the resulting treated water contains inorganic carbonate ions. These inorganic carbonate ions can cause degradation of the catalyst-loaded support in the hydrogen peroxide removal device, which poses a problem.

According to an embodiment of the present invention, the amount of TOC components

oxidatively decomposed in the second ultraviolet oxidation device can be maintained at or below a predetermined level by controlling or adjusting the ultraviolet irradiation dose of the first and second ultraviolet oxidation devices such that the difference ΔTOC ($\text{TOC}_{\text{SUP}} - \text{TOC}_{\text{TRE}}$) between the TOC value (TOC_{SUP}) of feed water to be supplied to the second ultraviolet oxidation device and the TOC value (TOC_{TRE}) of water treated by the second ultraviolet oxidation device is 1 ppb or less. Thus, the concentration of inorganic carbonate ions in the effluent water from the second ultraviolet oxidation device can be kept at or below a predetermined level, thereby suppressing deterioration of the catalyst-loaded support in the downstream hydrogen peroxide removal device caused by inorganic carbonate ions, and enabling a stable supply of high-purity ultrapure water (i.e., operating the apparatus so that fluctuations in water quality are minimized).

[0040]

(Membrane degassing device)

The membrane degassing device is a device in which treated water from the hydrogen peroxide removal device flows into one chamber separated by a gas separation membrane, and the other chamber is depressurized, thereby transferring the gas contained in the treated water through the gas separation membrane to the other chamber and removing it. The gas separation membrane may be, for example, a hydrophobic polymer membrane such as a tetrafluoroethylene-based or polyolefin-based membrane formed into a hollow fiber membrane shape or the like.

Other degassing devices, such as vacuum degassing devices and thermal degassing devices, can be used to remove gases contained in the treated water from the hydrogen peroxide removal device, but when such other degassing devices are used, there is a risk that impurities may be mixed into the water from these devices or that impurities may leach into the water from the packing material of the device. In contrast, membrane degassing devices are particularly preferred as degassing devices because they do not cause the problems of impurities being mixed into or leached out of the water.

[0041]

(Non-regenerative ion exchange device)

The non-regenerative ion exchange device (cartridge polisher) is not particularly limited, provided that it is capable of removing impurities such as cations and anions from the treated water supplied from the hydrogen peroxide removal device, but examples of the device include: an ion exchange device having a mixed bed of strong acid cation exchange resin and strong base anion exchange resin (mixed-bed single-tower type); an ion exchange device having a single bed of strong base anion exchange resin (single-bed single-tower type); a double-layer ion exchange device including a single bed of strong base anion exchange resin at the inlet side and a

mixed bed of strong acid cation exchange resin and strong base anion exchange resin at the outlet side (double-layer single-tower type); and an ion exchange device including a resin tower with a single bed of strong basic anion exchange resin, located upstream, and a resin tower with a mixed bed of strong acid cation exchange resin and strong base anion exchange resin, located downstream (two-tower type).

Of these, the mixed-bed single-tower type ion exchange device is preferred because it causes little change in the pH of the treated water at any position within the device and allows for efficient ion exchange.

[0042]

In view of the foregoing, according to the ultrapure water production apparatus and ultrapure water production method of the embodiments of the present invention, hydrogen peroxide generated in the ultraviolet oxidation device can be removed in the downstream catalytic device while suppressing deterioration of the catalyst-loaded support, thereby providing an ultrapure water production apparatus and ultrapure water production method that can stably supply ultrapure water having good quality over a long period of time.

The ultrapure water production apparatus and ultrapure water production method according to the embodiments of the present invention can supply highly pure ultrapure water from which impurities such as organic matter, hydrogen peroxide, dissolved gases, ionic substances, and fine particles have been removed, and such ultrapure water is suitable for cleaning electronic components and electronic component manufacturing equipment.

Example

[0043]

<Confirmation test of correlation between the OH-type proportion of the catalytic resin and hydrogen peroxide removal performance>

As shown in Test Example 1 below, a test was conducted in which the water to be treated containing hydrogen peroxide was passed through a catalytic device (hydrogen peroxide removal device), and the test results showed a correlation between the OH-type proportion of the catalytic resin and hydrogen peroxide removal performance.

[0044]

(Test Example 1)

As shown in FIG. 3, an ion exchange resin container (column) 30 with an inner diameter of 31 mm and a height of 1 m, equipped with a mesh 32 on the bottom, was prepared as a container to be packed with catalytic resin. The mesh 32 is positioned to cover the outlet for treated water at

the bottom of the container 30, acting as a filter that allows water to pass through while preventing the catalytic resin filled in the container from leaking out of the container. Next, catalytic resin 31 was filled to a height (layer height) of 10 cm. A test was conducted using the container packed with the catalytic resin 31 in this way as a catalytic device (hydrogen peroxide removal device).

As forms of the catalytic resin 31 filled in the container 30, there were prepared: layered forms comprising CO₃-type catalytic resin and OH-type catalytic resin in different mass ratios (CO₃-type/OH-type = 30/70, 50/50, 70/30, 90/10); and a single layer form of CO₃-type catalytic resin (CO₃-type/OH-type = 100/0). As the OH-type catalytic resin, a Pd-loaded strong base anion exchange resin (product name: ORLITE^(R) HR43-HG), manufactured by Organo Corporation, was used. As the CO₃-type catalytic resin, a carbonate type (CO₃-type) catalytic resin obtained by passing carbonated water through the OH-type catalytic resin was used. The catalytic resin was considered to have completely converted to the carbonate type (CO₃-type) when the resistivity values at the inlet and outlet during water passage became the same. Each of these catalyst resins was filled into the container (column) 30 as described above to prepare a catalytic device.

[0045]

Next, the water to be treated with an H₂O₂ concentration of 35 ppb (μg/L) was prepared and passed through the catalytic device at a flow rate of LV425 (the water to be treated was supplied from the top of the container 30 and the treated water was discharged from the bottom of the container 30), and the H₂O₂ concentration of the effluent water (treated water) one hour after the start of water flow was measured by colorimetric analysis using phenolphthalein. The results of Test Example 1 are shown in FIG. 2 (the curve shows the results of Test Example 1).

FIG. 2 shows the correlation between the OH-type proportion of the ion exchange resin after water flow and hydrogen peroxide removal performance. The vertical axis of FIG. 2 indicates the H₂O₂ concentration (μg/L) of the treated water, the horizontal axis (lower horizontal axis) indicates the OH-type proportion of the catalytic resin (Pd(OH) proportion (%)), and the upper horizontal axis indicates the CO₃-type proportion of the catalytic resin (Pd(CO₃) proportion (%)).

As shown in FIG. 2, the lower the OH-type proportion (Pd(OH) proportion) (i.e., the higher the CO₃-type proportion), the higher the H₂O₂ concentration in the treated water and the lower the hydrogen peroxide removal performance.

[0046]

<Test for confirming deterioration of catalytic resin due to inorganic carbonate ion and ultraviolet irradiation conditions (ΔTOC of 1 ppb or less)>

As shown in Test Example 2 below, a test was conducted in which the water to be

treated containing hydrogen peroxide and carbonic acid (inorganic carbonate ion) was passed through a catalytic device (hydrogen peroxide removal device), and it was confirmed that the catalytic resin deteriorated.

Furthermore, the results of this test confirmed that if the amount of decomposition of TOC component (equivalent to ΔTOC) in an ultraviolet oxidation device (second ultraviolet oxidation device) upstream of the catalytic device is 1 ppb or less, the deterioration of the catalytic resin in the downstream catalytic device can be sufficiently suppressed.

[0047]

(Test Example 2)

The test was conducted using a scaled-up larger-scale apparatus compared to Test Example 1 above.

A tank made of FRP (Fiberglass Reinforced Plastics) having an inner diameter of 320 mm was packed with non-regenerative ion exchange resin to a height of 80 cm and catalytic resin to a height of 10 cm, in that order. A strainer was provided at the bottom of the tank to allow water to pass through while preventing leakage of the ion exchange resin. A purified ion exchange resin (product name: ESP-2) manufactured by Organo Corporation was used as the non-regenerative ion exchange resin, and a Pd-supported strong base anion exchange resin (product name: ORLITE (registered trademark) HR43-HG), manufactured by Organo Corporation, was used as the catalytic resin.

The water to be treated was supplied from the top of the tank, passed through the catalytic resin and subsequently through the non-regenerative ion exchange resin, and treated water was discharged from the bottom of the tank. The carbonate concentration of the water to be treated (feed water) was 5 ppb ($\mu\text{g/L}$), the H_2O_2 concentration was 35 ppb ($\mu\text{g/L}$), and the flow rate was $3.4 \text{ m}^3/\text{h}$.

The H_2O_2 concentration of the effluent water (treated water) from the tank was periodically measured by colorimetric analysis using phenolphthalein, and for the catalytic resin at the time of the measurement, the OH-type proportion (Pd(OH) proportion) of the catalytic resin at the time of the H_2O_2 concentration measurement was calculated based on the carbonate concentration and the flow volume of the water to be treated (feed water), the exchange capacity of the catalytic resin, and the like. To verify the absence of any discrepancy between the calculated value and the measured value, the OH-type proportion of the catalytic resin was measured at a single point, and consistency was confirmed. The OH-type proportion of the catalytic resin was measured by titration. In this titration measurement, sodium nitrate solution, hydrochloric acid, and ammonia were passed through each sample resin, and the ion exchange capacities of the OH-

type, CO_3^{2-} -type, and Cl^- -type ions were individually measured. The ratio (%) of the ion exchange capacity of each ion type to the sum of these ion exchange capacities (total ion exchange capacity) was calculated, and the OH-type proportion of the sample resin was determined based on the obtained values.

The results of Test Example 2 are presented in FIG. 2 (the broken line indicates the results of Test Example 2).

[0048]

FIG. 2 shows the relationship between the OH-type proportion (Pd(OH) proportion) of the catalytic resin after water passage and the H_2O_2 concentration in the treated water. The vertical axis of FIG. 2 indicates the H_2O_2 concentration ($\mu\text{g/L}$) of the treated water, the lower horizontal axis indicates the OH-type proportion (Pd(OH) proportion (%)) of the catalytic resin, and the upper horizontal axis indicates the proportion of catalytic resin in which OH has been replaced by inorganic carbonate ions (CO_3 -type proportion: Pd(CO_3) proportion (%)).

As shown in FIG. 2, it can be seen that as the OH-type proportion (Pd(OH) proportion (%)) of the catalytic resin decreases (i.e., as the Pd(CO_3) proportion increases), that is, as the catalytic resin deteriorates, the H_2O_2 concentration in the treated water increases.

[0049]

Specifically, the H_2O_2 concentration was 1 ppb ($\mu\text{g/L}$) or less until passage of the water to be treated having a carbonate concentration of 5 ppb ($\mu\text{g/L}$) for 8 months, and the Pd(OH) proportion at that time was 60%.

This shows that if the carbonate concentration of the water to be treated is 5 ppb or less, the H_2O_2 concentration can be sufficiently reduced over a long period of time, i.e., deterioration of the catalytic resin can be sufficiently suppressed.

As described above, the ratio of TOC value to inorganic carbonate ion concentration (TOC value : inorganic carbonate ion concentration) is 1:5, and therefore a carbonate concentration of 5 ppb (corresponding to the maximum concentration of dissociated inorganic carbonate ions) corresponds to a TOC value of 1 ppb. Accordingly, if the amount of decomposition of TOC components (equivalent to ΔTOC) in an ultraviolet oxidation device upstream of the catalytic device is 1 ppb or less, it follows that deterioration of the catalytic device downstream can be sufficiently suppressed.

Explanation of Reference Signs

[0050]

1 Primary pure water production apparatus

- 2 Secondary pure water production apparatus
- 11 First ultraviolet oxidation device
- 12 Ion exchange device
- 13 Boron selective resin device
- 5 14 Degassing device
- 21 Second ultraviolet oxidation device
- 22 Hydrogen peroxide removal device (catalytic device)
- 23 Degassing device
- 24 Ion exchange device
- 10 25 Ultrafiltration membrane device
- 30 Ion exchange resin container (column)
- 31 Catalytic resin
- 32 Mesh

Claims

[Claim 1]

An ultrapure water production apparatus comprising:

a primary pure water production apparatus and a secondary pure water production apparatus,

wherein the primary pure water production apparatus comprises a first ultraviolet oxidation device,

the secondary pure water production apparatus comprises a second ultraviolet oxidation device and a hydrogen peroxide removal device provided downstream of the second ultraviolet oxidation device,

the hydrogen peroxide removal device comprises an ion-exchange material supporting a platinum-group metal catalyst, and

the ultraviolet irradiation dose of the second ultraviolet oxidation device is controlled such that a difference ΔTOC ($\text{TOC}_{\text{SUP}} - \text{TOC}_{\text{TRE}}$) between a TOC value (TOC_{SUP}) of feed water to be supplied to the second ultraviolet oxidation device and a TOC value (TOC_{TRE}) of water treated by the second ultraviolet oxidation device is 1 ppb or less.

[Claim 2]

The ultrapure water production apparatus according to claim 1, wherein the ultraviolet radiation dose of the first ultraviolet oxidation device is controlled such that the TOC value (TOC_{SUP}) of feed water to be supplied to the second ultraviolet oxidation device satisfies $0 < \text{TOC}_{\text{SUP}} \leq 5$ ppb.

[Claim 3]

The ultrapure water production apparatus according to claim 1, wherein the ultraviolet irradiation dose of the first ultraviolet oxidation device is greater than the ultraviolet irradiation dose of the second ultraviolet oxidation device.

[Claim 4]

The ultrapure water production apparatus according to claim 1, wherein the ultraviolet irradiation dose of the first ultraviolet oxidation device and the ultraviolet irradiation dose of the second ultraviolet oxidation device are controlled such that the TOC value (TOC_{TRE}) of water treated by the second ultraviolet oxidation device is 1 ppb or less.

[Claim 5]

The ultrapure water production apparatus according to claim 1 comprises a water quality meter provided upstream of and/or downstream of the second ultraviolet oxidation device, including further downstream thereof.

[Claim 6]

The ultrapure water production apparatus according to claim 1 comprises a first TOC meter provided upstream of the second ultraviolet oxidation device and a second TOC meter provided downstream of the second ultraviolet oxidation device, including further downstream thereof.

[Claim 7]

A method for producing ultrapure water using an ultrapure water production apparatus comprising a primary pure water production apparatus and a secondary pure water production apparatus,

wherein the primary pure water production apparatus comprises a first ultraviolet oxidation device,

the secondary pure water production apparatus comprises a second ultraviolet oxidation device and a hydrogen peroxide removal device provided downstream of the second ultraviolet oxidation device,

the hydrogen peroxide removal device comprises an ion-exchange material supporting a platinum-group metal catalyst, and

the method comprises adjusting the ultraviolet irradiation dose of the second ultraviolet oxidation device such that a difference ΔTOC ($\text{TOC}_{\text{SUP}} - \text{TOC}_{\text{TRE}}$) between a TOC value (TOC_{SUP}) of feed water to be supplied to the second ultraviolet oxidation device and a TOC value (TOC_{TRE}) of water treated by the second ultraviolet oxidation device is 1 ppb or less.

[Claim 8]

The method for producing ultrapure water according to claim 7, wherein the ultraviolet irradiation dose of the first ultraviolet oxidation device is adjusted such that the TOC value (TOC_{SUP}) of feed water to be supplied to the second ultraviolet oxidation device satisfies $0 < \text{TOC}_{\text{SUP}} \leq 5$ ppb.

[Claim 9]

The method for producing ultrapure water according to claim 7, wherein the ultraviolet irradiation dose of the first ultraviolet oxidation device is adjusted to be greater than the ultraviolet irradiation dose of the second ultraviolet oxidation device.

[Claim 10]

The method for producing ultrapure water according to claim 7, wherein the ultrapure water production apparatus comprises a first TOC meter provided upstream of the second ultraviolet oxidation device and a second TOC meter provided downstream of the second ultraviolet oxidation device, including further downstream thereof.