sterilize liquid 803, which were problems.

[0004] Therefore, in order to improve the generation efficiency of the plasma while lowering the applied voltage, a liquid treatment apparatus in which a gas introduced from the outside is interposed between both electrodes is known (refer to Japanese Patent No. 4041224). In the liquid treatment apparatus (Fig. 16) disclosed in Japanese Patent No. 4041224, a pulse voltage is applied between anode electrode 901 and cathode electrode 902 while interposing target treatment liquid 903 and gas 904 (for example, oxygen) between anode electrode 901 and cathode electrode 902. The plasma is generated in gas 904 by applying the pulse voltage, and a plasma treatment is performed on liquid 803 to sterilize the liquid. According to the liquid treatment apparatus disclosed in Japanese Patent No. 4041224, it is possible to decrease the applied voltage as compared with the case where the gas is not interposed, and to efficiently generate plasma to sterilize target treatment liquid 903.

[0005] If a treatment liquid treated with such a liquid treatment apparatus is supplied to a tank or the like containing a culture liquid for plant cultivation, an apparatus which is capable of growing a plant with sterilized water can be considered.

SUMMARY

[0006] According to an aspect of the present disclosure, there is provided a liquid treatment apparatus including a treatment tank which generates a gas phase in the vicinity of a rotating center of a rotating flow of a liquid by rotating the liquid introduced from an introduction portion around a central axis, and includes a discharging portion for discharging the liquid introduced from the introduction portion as a treatment liquid, after the rotating flow is generated by rotating the liquid

between the introduction portion and

the discharging portion; a first electrode in which at least a portion is disposed in the treatment tank so as to be in contact with the liquid in the treatment tank; a second electrode which is disposed so as to be in contact with the liquid in the treatment tank; a power source which applies a voltage between the first electrode and the second electrode, generates a plasma in the gas phase, sterilizes the liquid so as to form the treatment liquid, and generates a modifying component which is a component having oxidizing power derived from the liquid in the treatment liquid; a microbubble generator which includes a microbubble generating chamber having a longitudinal sectional area larger than an opening of the discharging portion of the treatment tank, generates microbubbles or nanobubbles by discharging the treatment liquid from the discharging portion of the treatment tank in the microbubble generating chamber, and diffuses the generated microbubbles or nanobubbles in the treatment liquid; a target treatment tank which holds a culture liquid for plant cultivation, sterilizes the culture liquid with the treatment liquid supplied from the microbubble generator, and discharges sterilized target treatment water to the treatment tank as at least a portion of the liquid; a pump which is capable of circulating the liquid introduced in the treatment tank from the introduction portion of the treatment tank via the microbubble generator, between the treatment tank and the target treatment tank, wherein the plasma is generated in the gas phase of the rotating flow formed between the introduction portion and the discharging portion with the liquid, the liquid is sterilized, the modifying component is generated, the generated modifying component is dissolved in the treatment liquid to be dispersed in the treatment liquid, and the target treatment water which is discharged after the culture liquid is sterilized by introducing the treatment liquid to the target treatment tank via

the microbubble generator is introduced to the treatment tank as at least a

portion of the liquid by the pump.

[0007] In the liquid treatment apparatus according to the aspect of the disclosure, the liquid is vaporized in the rotating flow, the pulse voltage is applied to the generated gas phase to generate plasma, so that the liquid can be sterilized, and the treatment liquid containing the modifying component having a sterilization action can be generated. Since it is unnecessary to vaporize the liquid by application of voltage, it is possible to efficiently generate the plasma with low electric power, efficiently and quickly sterilize the liquid and the target treatment water, and shorten the treatment time, thereby increasing sterilization capacity. In addition, since the sterilization treatment of the liquid and the target treatment water is performed without introducing air from the outside, the discharging of electricity is stabilized and generation of nitrous acid, which is a harmful substance, can be suppressed.

BRIEF DESCRIPTION OF THE DRAWINGS

[0008] FIG. 1 is a side sectional view illustrating a configuration of a liquid treater of a liquid treatment apparatus according to an Embodiment 1 of the disclosure;

FIG. 2 is a side sectional view of an apparatus main body;

FIG. 3 is a diagram seen from a cross-section taken along line in 3-3 of FIG. 2;

FIG. 4 is a side sectional view illustrating a state where a rotating flow is generated in a treatment tank, and a voltage is not applied;

FIG. 5 is a diagram seen from a cross-section taken along line in 5-5 of FIG. 4;

FIG. 6A is a side sectional view illustrating a state where a rotating flow is generated in a treatment tank, and a voltage is applied;

WHAT IS CLAIMED IS:

1. A liquid treatment apparatus comprising:

a treatment tank which generates a gas phase in a vicinity of a rotating center of a rotating flow of a liquid by rotating the liquid introduced from an introduction portion around a central axis, and includes a discharging portion for discharging the liquid introduced from the introduction portion as a treatment liquid after the rotating flow is generated by rotating the liquid between the introduction portion and the discharging portion;

a first electrode in which at least a portion is disposed in the treatment tank so as to be in contact with the liquid in the treatment tank;

a second electrode which is disposed so as to be in contact with the liquid in the treatment tank;

a power source which applies a voltage between the first electrode and the second electrode, generates a plasma in the gas phase, sterilizes the liquid so as to form the treatment liquid, and generates a modifying component which is a component having oxidizing power derived from the liquid in the treatment liquid;

a microbubble generator which includes a microbubble generating chamber having a longitudinal sectional area larger than an opening of the discharging portion of the treatment tank, generates microbubbles or nanobubbles by discharging the treatment liquid from the discharging portion of the treatment tank in the microbubble generating chamber, and diffuses the generated microbubbles or nanobubbles in the treatment liquid;

a target treatment tank which holds a culture liquid for plant cultivation, sterilizes the culture liquid with the treatment liquid supplied from

the microbubble generator, and discharges sterilized target treatment water to the treatment tank as at least a portion of the liquid; and

a pump which is capable of circulating the liquid introduced in the treatment tank from the introduction portion of the treatment tank via the microbubble generator, between the treatment tank and the target treatment tank,

wherein the plasma is generated in the gas phase of the rotating flow formed between the introduction portion and the discharging portion with the liquid, the liquid is sterilized, the modifying component is generated, the generated modifying component is dissolved in the treatment liquid to be dispersed in the treatment liquid, and the target treatment water which is discharged after the culture liquid is sterilized by introducing the treatment liquid to the target treatment tank via the microbubble generator is introduced to the treatment tank as at least a portion of the liquid by the pump.

2. The liquid treatment apparatus according to claim 1,

wherein the liquid is water, and

wherein the modifying component which is a component having oxidizing power derived from the liquid is hydrogen peroxide.

3. The liquid treatment apparatus according to claim 1 or claim 2, further comprising:

a fertilizing device which is disposed between the microbubble generator and the target treatment tank, and performs fertilization on the treatment liquid to be supplied to the target treatment tank.

4. The liquid treatment apparatus according to claim 3, further

comprising:

an electrical characteristic measuring device which is disposed between the microbubble generator and the fertilizing device, and measures pH or electric conductivity of the treatment liquid supplied from the microbubble generator; and

a fertilization controller which controls a fertilization operation of the fertilizing device based on a measurement result obtained by the electrical characteristic measuring device.

5. The liquid treatment apparatus according to claim 4, further comprising:

a hydrogen peroxide concentration measuring device which is disposed between the treatment tank and the target treatment tank, and measures a concentration of hydrogen peroxide of the treatment liquid supplied from the microbubble generator;

a hydrogen peroxide removing device which is disposed downstream of a flow path of the treatment liquid than the hydrogen peroxide concentration measuring device, and removes the hydrogen peroxide from the treatment liquid;

a hydrogen peroxide removal controlling device which is connected to the hydrogen peroxide removing device, and controls an operation of removing of the hydrogen peroxide based on the measurement result of the concentration of the hydrogen peroxide measured by the hydrogen peroxide concentration measuring device; and

an oxygen supplier which introduces oxygen generated from the hydrogen peroxide removed by the hydrogen peroxide removing device to the treatment liquid.

6. The liquid treatment apparatus according to any one of claims 1 to 5, comprising:

a liquid measurement sensor which is disposed between the target treatment tank and the treatment tank, and measures a liquid amount or a liquid pressure of the liquid to be introduced into the treatment tank; and

a treatment liquid controller which controls the power source based on a measurement result obtained by the liquid measurement sensor.

7. The liquid treatment apparatus according to any one of claims 1 to 6,

wherein the first electrode is disposed so as to be in contact with the gas

phase generated in the vicinity of the rotating center of the rotating flow of the liquid, or disposed so as to be positioned in a vicinity of the gas phase.

8. The liquid treatment apparatus according to any one of claims 1 to 7,

wherein the liquid introduced from the introduction portion of the treatment tank contains the target treatment water discharged from the target treatment tank.

9. The liquid treatment apparatus according to claim 8,

wherein the treatment tank includes a cylindrical or truncated conical first inner wall which rotates the liquid supplied from the introduction portion to generate the rotating flow, and

wherein the first electrode is disposed on a central axis of the first inner wall or a vicinity of the central axis.

10. The liquid treatment apparatus according to claim 9,

wherein the first electrode is disposed on one end side of the central axis or the vicinity of central axis,

wherein the second electrode is disposed on another end side of the central axis or the vicinity of central axis,

wherein the introduction portion is disposed on the one end side of the central axis, and

wherein the discharging portion is disposed on the other end side of the central axis.

11. The liquid treatment apparatus according to claim 10,

wherein the second electrode is a plate-shaped electrode disposed

in a portion around the central axis of or disposed so as to surround an entire circumference of the central axis of the first inner wall on the other end side of the first inner wall.

12. The liquid treatment apparatus according to claim 10,

wherein the second electrode is disposed on the side of the central axis of the first inner wall on the other end side of the first inner wall.

13. The liquid treatment apparatus according to claim 10,

wherein the second electrode is a cylindrical electrode disposed so as to surround a portion of or an entire circumference of the central axis of the first inner wall on the other end side of the first inner wall.