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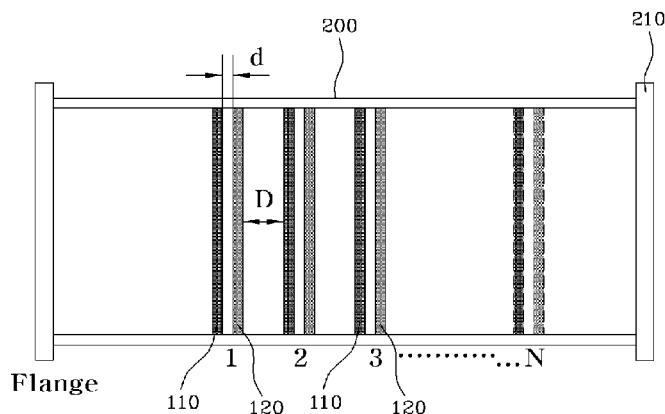
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(54) Title: ELECTRIC DISINFECTION GRID USING VIRTUAL ELECTRODES FOR TREATING INFECTED WATER AND
WATER TREATING SYSTEM USING THE SAME

[Fig. 7]



(57) Abstract: The present invention relates to a grid electrode for treating ballast water of a ship or other waste water, and, particularly, to a grid electrode, in which an anode and a cathode are disposed in a predetermined direction such that they are spaced apart from each other, so that a virtual electrode is formed between the anode and cathode, with the result that microbes can be killed by destroying their cell membranes and simultaneously electrochemical disinfection can be additionally conducted, and to a water treatment system comprising the same. The present invention provides a grid electrode for water treatment using a virtual electrode, comprising: an anode including a conductive metal wire which is vertically extended in a parallel zigzag pattern in a same plane; and a cathode including a conductive metal wire which is horizontally extended in a parallel zigzag pattern in a same plane, wherein the anode and cathode are spaced apart from each other such that the metal wire of the anode and the metal wire of the cathode intersect each other.

Description

ELECTRIC DISINFECTION GRID USING VIRTUAL ELECTRODES FOR TREATING INFECTED WATER AND WATER TREATING SYSTEM USING THE SAME

Technical Field

- [1] The present invention relates to an electric disinfection grid electrode for treating sea water, sewage water, waste water and the like, and, more particularly, to a grid electrode for water treatment using virtual electrodes, in which microbes and the like included in sea water and the like can be effectively removed using a direct-current (DC) power supply of low voltage and low current, and simultaneously chemical disinfection effects caused by hypochlorite produced by electrolysis using low current can also be obtained, and to a water treatment system using the same.

Background Art

- [2] The International Maritime Organization (IMO) has established and enforced various regulations for ballast water treatment since 1997 in order to preserve the coastal ecological environment and protect the health of the general public by minimizing the migration of harmful underwater microbes and disease-causing germs through ballast water. Currently, as a ballast water treatment method for disinfecting microbes of 50 μm or less, phytoplankton, zooplankton, E.coli, escherichia coli, toxic vibrio cholerae and the like, a filtering method, a chlorine disinfection method, an ultraviolet (UV) disinfection method, an ozone disinfection method, an electrolytic disinfection method or the like is being used.
- [3] The mechanical filtering method is disadvantageous in that high-priced filters must be used in order to filter out organisms of 5 ~ 10 μm and in that maintenance cost is increased because filters are corroded or clogged. Furthermore, this filtering method is also problematic in that disease-causing germs, such as bacteria and the like, cannot be removed.
- [4] U.S. patent No. 5816181 discloses a method of heating ballast water using the heat discharged from a ship's engine. When ballast water is maintained at a temperature of 35 ~ 45°C for a predetermined time, large organisms, such as small fish, can be killed, but small organisms, such as microbes, cannot be completely eliminated. Therefore, this method is disadvantageous in that the kill-rate of microbes is low and in that costs are increased because heat sources, heat exchangers, pumps and piping equipment must be additionally provided.
- [5] Currently, in chemical water treatment methods, chlorine dioxide (ClO_2) is being widely used as a biocidal agent. U.S. patent No. 6773611 discloses a chemical water

treatment method in which the concentration of chlorine dioxide in a ballast tank is automatically controlled using a chlorine disinfection apparatus. This chemical water treatment method requires facilities for loading a powdered or liquid biocidal agent in a ship and introducing the biocidal agent into a ballast water pipe line and then mixing the biocidal agent in ballast water or facilities for producing a strong active oxidizing disinfectant in a ship. These facilities are very complicated chemical process treatment systems, and are required to occupy sufficient space and to be strictly managed. Further, these facilities are most problematic in that chlorine oxides or acidic by-products having a harmful influence on a coastal ecosystem are produced, and thus an apparatus for preventing the production of the chlorine oxides or acidic by-products is additionally required.

- [6] Ozone (O_3) may exemplify a gaseous biocidal agent. U.S. patent No. 6125778 discloses a method of treating ballast water using ozone (O_3) produced from a ship. Since ozone is harmful to the human body, this method is disadvantageous in that it is required that ozone which is not dissolved by the sea water must be emitted from ballast water into the air when the ballast water is discharged, and in that large-size microbes cannot be killed.
- [7] U.S. Patent No. 7005074 discloses a method of disinfecting ballast water using ultraviolet (UV) rays. However, this method is problematic in that it is difficult to be used for turbid sea water, and in that microbes cannot be efficiently killed.
- [8] U.S. Patent No. 6800206 discloses an electrolytic disinfection method. In this method, underwater microbes or cells are killed by ions generated through electrolysis.
- [9] U.S. Patent No. 7244348 discloses an apparatus for producing a hypochlorite chemical biocidal agent by electrolyzing sea water on a voyage at sea. This apparatus has additional problems in that a high-voltage power supply is required to electrolyze sea water, chlorine oxides harmful to the natural environment are produced, and hydrogen produced by the electrolysis of water must be safely removed.

Disclosure of Invention

Technical Problem

- [10] Accordingly, the present invention has been made to overcome the above-mentioned problems, and the present invention provides a grid electrode for water treatment, which can effectively remove microbes, bacteria and other organisms present in water without causing conventional harmful side effects, and a water treatment system using the same.
- [11] That is, an object of the present invention is to provide a grid electrode for water treatment, in which production and maintenance costs can be reduced because it can be easily installed and maintained, and which can effectively remove microbes, bacteria

and other harmful organisms present in water even if only a small space for installing the grid electrode is provided, and a water treatment system comprising the same.

Technical Solution

- [12] The present invention has been made keeping in mind the above problems occurring in the related art, and an aspect of the present invention provides a grid electrode for water treatment using a virtual electrode, including: an anode including a conductive metal wire which is vertically extended in a parallel zigzag pattern in a same plane; and a cathode including a conductive metal wire which is horizontally extended in a parallel zigzag pattern in a same plane, wherein the anode and cathode are spaced apart from each other such that the metal wire of the anode and the metal wire of the cathode intersect each other.
- [13] Here, the anode may include a first plate-like frame and the conductive metal wire vertically extended in a parallel zigzag pattern and disposed on the first plate-like frame, and the cathode may include a second plate-like frame and the conductive metal wire horizontally extended in a parallel zigzag pattern and disposed on the second plate-like frame.
- [14] Each of the conductive metal wires of the anode and cathode may include at least one main line and a plurality of branch lines extending from the at least one main line parallel thereto.
- [15] The grid electrode may be connected to a direct-current (DC) power supply, and the DC power supply may supply current and voltage to the grid electrode such that the current and voltage does not exceed 50 V and 10 mA/cm², respectively.
- [16] The conductive metal wire may be made of one selected from among nickel (Ni), chromium (Cr), stainless steel, titanium (Ti), iridium (Ir) and alloys thereof.
- [17] Another aspect of the present invention provides a water treatment system comprising the grid electrode in a plural number, wherein the plurality of grid electrodes is disposed in series in a ballast water flow pipe of a ship at interval distances, and is connected to a direct-current (DC) power supply.
- [18] Here, microbial fluorometers for measuring a concentration of microbes included in water to be treated and flowing along the ballast water flow pipe may be provided at the front, rear or both sides of the grid electrodes.
- [19] A hydrogen gas detector for monitoring a concentration of hydrogen gas produced by the electrolysis of the water to be treated may be provided at the rear of the grid electrodes.
- [20] In this case, the current of the DC power supply may be automatically controlled when the concentration of the hydrogen gas detected by the hydrogen gas detector exceeds a predetermined value.

Advantageous Effects

- [21] The grid electrode of the present invention is advantageous in that its structure is simple, its production cost is low, and it can effectively remove microbes, bacteria and other harmful organisms included in water to be treated, such as various kinds of sewage-waste water including ballast water. Therefore, it is very excellent in terms of energy efficiency, and is very economical in terms of production cost.
- [22] In particular, since the grid electrode of the present invention can be conveniently installed in a ballast water flow pipe and the like, additional water treatment facilities are not required, and since it can be installed in a small space, it is very efficient in terms of space requirements.
- [23] Moreover, the grid electrode of the present invention is advantageous in that it can prevent the generation of environmental pollutants because it employs a method of killing and removing organisms by perforating their membranes and is operated using a low voltage and low current, and in that it has an immediate effect on the removal of microbes and the like.
- [24] Further, the grid electrode of the present invention and the water treatment system using the same can be widely used in the treatment of excretions in a ship or in the purification of general domestic water, waste water, sewage water and the like as well as in the treatment of ballast water.

Brief Description of Drawings

- [25] FIG. 1 is a view showing a grid electrode composed of an anode and a cathode according to the present invention;
- [26] FIG. 2 is a partially-cutaway perspective view showing a water treatment system in which the grid electrodes are serially arranged in a ballast water flow pipe according to an embodiment of the present invention;
- [27] FIG. 3 is a view showing the state in which a power supply is connected between the anode and cathode according to the present invention;
- [28] FIG. 4 is a schematic view showing an example of virtual electrodes formed by the grid electrode according to the present invention;
- [29] FIG. 5 is a graph showing the current flow between the virtual electrode and its adjacent electrode according to the present invention;
- [30] FIG. 6 is a view showing the formation of the virtual electrode between the anode and cathode according to the present invention;
- [31] FIG. 7 is a schematic sectional view showing a water treatment system according to an embodiment of the present invention;
- [32] FIG. 8 is a schematic sectional view showing a water treatment system according to another embodiment of the present invention; and

- [33] FIGS. 9 and 10 are views showing modified grid electrodes according to the present invention.

Best Mode for Carrying out the Invention

- [34] The present invention relates to an apparatus for disinfecting microbes, colon bacilli, bacteria and the like present in ballast water using electroporation, in which a cell membrane is destroyed by an electric field formed by applying a direct current to sea water, or using hypochlorite having strong oxidative activity, which is obtained from the electrolysis of sea water by a direct current. In the present invention, the apparatus is a disinfection apparatus in which grid electrodes, each including an anode and a cathode made of conductive wire, are installed in a ballast water flow pipe at predetermined distances, and a voltage is applied thereto, so that electric current flows through the total space between the anode and the cathode, thereby destroying all microbes and bacteria included in sea water using electrical shock or hypochlorite.
- [35] In the above disinfection apparatus, since the grid electrodes are repeatedly disposed in the ballast water flow pipe, all microbes and bacteria present in sea water are completely killed while the water to be treated flows through the pipe. Furthermore, in the above disinfection apparatus, since ballast water is treated only when it is introduced into the ballast water flow pipe or is discharged therefrom, this disinfection apparatus has low power consumption and high efficiency, and since the grid electrodes are installed in the ballast water flow pipe, additional space for installing the grid electrodes is not required.
- [36] Further, the present invention relates to an electric disinfection grid electrode using three-dimensional virtual electrodes, in which microbes and disease-causing germs including colon bacilli included in sea water, waste water and sewage water can be killed by applying a direct voltage of 50 V or less thereto at a current density of 10 mA/cm² using electroporation or hypochlorite produced by the electrochemical reaction of sodium chloride in sea water, and to a water treatment system using the same.
- [37] In molecular biology, bioprobes or medicines are administered into cells using electroporation. When a potential difference of 1 V or more is generated around a cell membrane which is a nonconductor, holes are formed in the cell membrane due to dielectric breakdown, and, at this time, the bioprobes or medicines are instantaneously administered into the cells through the holes. In this case, the holes must be instantaneously opened, and, if a voltage is continuously applied to the cells, the cells are killed.
- [38] The present invention is used to disinfect microbes using this phenomenon. That is, in the present invention, a low voltage current is applied to sea water which is a

conductor, so that a potential difference of 1 V or more is generated around a cell membrane, with the result that the cell membrane dielectrically breaks down, thereby permanently killing the microbes. Generally, since the thickness of a cell membrane is only several micrometers, the cell membrane dielectrically breaks down even when only a potential difference of 1 V is generated therearound.

- [39] Further, in the present invention, in addition to the method of killing microbes using an electric field, hypochlorite having strong oxidizing power is produced by the low-voltage electrochemical reaction of sodium chloride in sea water while minimizing the production of hydrogen, and, due to the oxidation of the hypochlorite, the microbes are killed.
- [40] FIG. 1 is a view showing a grid electrode composed of an anode and a cathode according to the present invention, FIG. 2 is a partially-cutaway perspective view showing a water treatment system in which the grid electrodes are serially arranged in a ballast water flow pipe according to an embodiment of the present invention, and FIG. 3 is a view showing the state in which a power supply is connected between the anode and cathode according to the present invention. As shown in FIGS. 1 to 3, a grid electrode 100 of the present invention is composed of an anode 110 and a cathode 120. The anode 110 is configured such that a conductive metal wire 114 is vertically extended in a parallel zigzag pattern in the same plane, and the cathode 120 is configured such that a conductive metal wire 124 is horizontally extended in a parallel zigzag pattern in the same plane. In the grid electrode 100, the anode 110 and cathode 120 are spaced apart from each other such that the metal wire 114 of the anode 110 and the metal wire 124 of the cathode 120 intersect each other. Here, the metal wires 114 and 124 may be made of one selected from among silver (Ag), nickel (Ni), chromium (Cr), stainless steel, titanium (Ti), iridium (Ir) and alloys thereof, which have excellent corrosion resistance.
- [41] In the present invention, the anode 110 and cathode 120 are fixed on different frames 112 and 122, respectively, such that the anode 110 and cathode 120 are not flush with each other and are installed in a ballast water flow pipe 200 with a predetermined distance therebetween. The sufficient residence time for microbes or bacteria in sea water or waste water to interact with the current flow can be obtained by adjusting the distance between the anode 110 and cathode 120. Due to the adjustment of the distance between the anode 110 and cathode 120, the flow rate of direct voltage and current can be controlled such that a sufficient disinfection effect of microbes or bacteria can be exhibited without electrolyzing a large amount of water. When the anode 110 and cathode 120 are arranged such that they intersect each other, since the resistance value of sea water is lowest at the point of intersection of the positive metal wire 114 with the negative metal wire 124, at which point the distances between the positive metal

wire 114 and negative metal wire 124 are the smallest, the largest amount of current flows at the intersection point by Ohm's law, thereby forming virtual electrodes. Current freely flows from the virtual electrodes to the electrodes adjacent the virtual electrodes, with the result that an average current uniformly flows over the entire space, so that microbes or bacteria are destroyed or killed by electrical shock of a direct voltage of 50 V or less and a current density of 10 mA/cm². As such, when the grid electrodes 100, each of which is composed of the anode and cathode, are repeatedly installed in the ballast water flow pipe at predetermined distances, microbes or bacteria which are not killed while they pass through the first grid electrode are completely killed while they pass through subsequent grid electrodes, such as the second, third, fourth... electrodes. Simultaneously with this, in the present invention, low current and low voltage are applied to the grid electrode, so that hypochlorite having strong oxidizing power is produced by the electrochemical reaction of sodium chloride in sea water, with the result that organic microbes are oxidized by the hypochlorite, thereby killing the organic microbes.

[42] It was reported in the publication (Zimmerman, U., G. Pilwat, and F. Riemann, "Dielectric breakdown of cell membranes", *Biophys. J.* 1974 Nov;14(11):88199.) that, when a potential difference of 1 V or more is formed around a cell membrane of a microbe, holes are formed in the cell membrane by dielectric breakdown, and cell contents are discharged to the outside of the cell through the holes by electroporation, thereby destroying the cellular textures of microbes.

[43] Sea water has high electric conductivity because sodium chloride (NaCl) and other salts are dissolved therein. For example, the average electric conductivity of sea water having a salinity of 30 ppt at a temperature of 20°C is 35400 S/cm, approximately 30 Ohm/cm. When direct current is applied to a sea water flow pipe connected to a ballast tank at a current density of about 10 mA/cm² for about 1 ms (0.001 second), microbes included in the sea water are completely killed. For this reason, the distance between the anode 110 and cathode 120 are determined such that the time taken the sea water to pass through the anode 110 and cathode 120 is 1 ms (0.001 second) or more.

[44] In the present invention, water treatment is not conducted by providing a plurality of anode and cathode spots, and the infinite anode and cathode spots are not fabricated into real electrodes. That is, in the present invention, as shown in FIG. 1, grids are formed by arranging metal wires in one direction, and, as shown in FIG. 2, the anode 110 and cathode 120 are provided in a water flow pipe 200 such that they face each other at right angles.

[45] FIG. 4 is a schematic view showing an example of virtual electrodes formed by the grid electrode according to the present invention. In FIG. 4, A, B and C points of the metal wire 114 of the anode 110 correspond to A', B' and C' points of the metal wire

124 of the cathode 120. That is, when perpendicular lines are respectively drawn from the A, B and C points of the metal wire 114 of the anode 110 onto the metal wire 124 of the cathode 120, the perpendicular lines meet the A', B' and C' points of the metal wire 124 of the cathode 120, respectively. Therefore, the straight lines AA', BB' and CC' are shortest, so that the resistance values of sea water on these straight lines are lowest, with the result that the highest current flows on these straight lines. In other words, the A and A', B and B' and C and C' function as point electrodes. In the present invention, many virtual electrode points are realized by forming metal wires, which can be easily fabricated, into line grids without really fabricating these point electrodes. Further, in FIG. 4, G is an intermediate point of A and B, and G' is an intersection point of AB' and BA'.

[46] FIG. 5 is a graph showing the current flow between the virtual electrode and its adjacent electrode according to the present invention, and FIG. 6 is a view showing the formation of the virtual electrode between the anode and cathode according to the present invention. In FIG. 5, the line drawn from the top left to the bottom right represents the intensity of current flowing from the anode spot A to the virtual cathode spot B' adjacent to the cathode spot A'. Here, a maximum current of i_2 flows between AA', and a current of i_1 , which is smaller than i_2 , flows between AB' because the distance of AB' is larger than that of AA'. From FIG. 4, it can be seen that current flows from the virtual anode spot A to the virtual cathode spot B' or from the virtual anode spot B to the virtual cathode spot A'. Since this current field is an open field, as shown in FIG. 6, current flows from the anode spot A to the virtual cathode spots B', C', D' ..., but, for convenience, FIG. 5 shows only the current flow from the anode spot A to the adjacent spot thereof.

[47] Since current flows from the respective spots of the anode to all spots of the cathode in vertical and longitudinal directions, as shown in FIG. 6, it can be seen that the average integrated current in each current field is $i = i_1 + i_2$, which is constant. Since this constant current flows over the entire region between the anode 110 and cathode 120 in the ballast water flow pipe, the microbes passing through this region are killed by the dielectric breakdown caused by a potential difference of 1 V or more between the inside and outside of cell membrane in the electric field formed by current flow.

[48] FIG. 7 is a schematic sectional view showing a water treatment system according to an embodiment of the present invention, and FIG. 8 is a schematic sectional view showing a water treatment system according to another embodiment of the present invention. In FIG. 7, the distance (d) between the anode 110 and cathode 120 and the distance (D) between the grid electrodes are set to have sufficient contact time in consideration of the flow rate of ballast water in the conduit of a ballast water treatment apparatus such that the disinfection of microbes through electroporation can be

conducted by sufficiently exposing the microbes to the current field. For example, in FIG. 7, the distance (d) between the anode 110 and cathode 120 is determined such that the flow rate of ballast water passing through the anode and cathode 110 and 120 is 1 ms (0.001 s) or more, and the distance (D) between the grid electrodes is determined to allow a delay time of 10 ms. In order to apply a current density of 10 mA/cm² or more to the electric field, DC voltage is increased in proportion to the increases in the distances 'd' and 'D'.

[49] About 28 g/L of sodium chloride is dissolved in sea water, and this sodium chloride serves to increase the electric conductivity of the sea water. Due to the electrochemical reaction of sodium chloride in the sea water, sodium hypochlorite (NaOCl) having strong oxidizing power against organic substances and hydrogen gas are produced through the following chemical reaction.

[50] $\text{NaCl} + \text{H}_2\text{O} + 2\text{e} \rightarrow \text{NaOCl} + \text{H}_2$

[51] The hypochlorite produced by this electrochemical reaction additionally kill microbes or bacteria in addition to the above electroporation. As represented by the above chemical reaction formula, during the electrochemical reaction, in addition to hypochlorite, hydrogen gas is also produced. In this case, since the production rate of hydrogen gas is proportionate to current density, in FIG. 8, the current density is automatically controlled using a DC power supply 300 such that the production rate of hydrogen gas does not exceed 0.1%, which is 1/40 of the lowest safety explosion level of 4%, by monitoring the amount of the produced hydrogen gas using a hydrogen gas detector 310. This very small amount of hydrogen gas is introduced into a ballast tank together with ballast water and then discharged to the outside of the ballast tank through an exhaust port of the ballast tank. The hydrogen gas detector 310 may be provided at the rear of the grid electrode 100.

[52] As described above, in the present invention, microbes, disease-causing germs such as colon bacilli and the like included in sea water, waste water and sewage water are killed using electroporation and hypochlorite. When microbes and the like are not completely killed by a pair of grid electrodes 100, as shown in FIG. 7, several pairs of grid electrodes may be serially disposed at distances (D).

[53] Microbial fluorometers 320 may be provided at the front, rear or both sides of the grid electrodes 100 acting as a microbial disinfection unit. The microbial fluorometer serves to measure the concentration of the microbes infiltrated in the ballast water flow pipe 200 and thus to allow the DC power supply 300 to automatically control the voltage and current density suitable for each of the grid electrodes 100. In this case, the distance between each pair of the grid electrodes 100 may be set such that microbes can stay in the electric field for 10 ms regardless of the flow rate of ballast water, and the direct-current voltage applied to the grid electrodes 100 may be controlled to have

desired values.

- [54] All biological tissues contain nicotinamide adenine dinucleotide (NADH) serving to assist metabolism. When this NADH is irradiated with ultraviolet light having a wavelength of 340 nm, blue fluorescence having a wavelength of 460 nm is exhibited. Thus, the concentrations of microbes, colon bacilli and the like can be monitored using this fluorescence intensity.
- [55] As a result of monitoring the kill rate of microbes and the like using the microbial fluorometer 320 provided at the rear of the grid electrodes 100, when the kill rate thereof is not sufficient, the killing of microbes, disease-causing germs and the like may be completely conducted by increasing the number of the grid electrodes 100 or increasing the current density.
- [56] In order to remove the dregs interposed between the anode 110 and cathode 120 of each of the grid electrodes 100, as shown in FIG. 8, ballast water may be discharged in a direction opposite to the intake of the ballast water.
- [57] As described above, the present invention relates to an apparatus for killing microbes and disease-causing germs included in sea water by applying a direct voltage of 50 V thereto at a current density of 10 mA/cm² through electroporation using several pairs of grid electrodes 100 installed in the ballast water flow pipe. Further, the present invention relates to an apparatus for killing microbes and disease-causing germs included in sea water using hypochlorite produced by the electrochemical reaction of sodium chloride in the sea water by applying current to the sea water.
- [58] Moreover, the present invention related to an apparatus for disinfecting sea water such that the contents of ecosystem-destructible organisms, such as zooplankton, phytoplankton, zebra mussel, and bacteria harmful to public health, such as escherichia coli, vibrio cholerae and the like, included in ballast water of large-size ships, are below the standard values determined by the International Maritime Organization (IMO). This apparatus for disinfecting sea water is advantageous in that energy consumption and operation costs can be minimized because of low power consumption, in that space for installing grid electrodes is not required because several pairs of the grid electrodes are installed in the ballast water flow pipe, and in that the burden felt by the ship in terms of the energy required for operation due to the load of conventional additional devices is greatly decreased because the weight of this apparatus is reduced.
- [59] The electroporation employing the grid electrodes 100 for water treatment using virtual electrodes can be widely used in the treatment of excretions in a ship or in the purification of general domestic water, waste water, sewage water and the like as well as in the treatment of ballast water. Further, according to the water treatment system of the present invention, since the grid electrodes can be provided in the ballast water flow pipe, an additional space for installing the grid electrodes is not required, and

since the water treatment system can be operated only when ballast water is introduced into and discharged from the ballast water flow pipe, its operation efficiency is higher than those of conventional water treatment systems.

- [60] FIGS. 9 and 10 are views showing modified grid electrodes 101 and 102 according to another embodiment of the present invention, respectively. In FIGS. 9 and 10, the reference numerals 114a, 114b, 114c and 114d indicate metal wires constituting anodes, and the reference numerals 124a, 124b, 124c and 124d indicate metal wires constituting cathodes. In the embodiment shown in FIG. 1, when metal wires 114 and 124 are respectively disposed on frames 112 and 122, a strand of each of the metal wires 114 and 124 is zigzagged on each of the frames 112 and 122 from the beginning to the end to fabricate the anode or cathode. However, in these embodiments, a plurality of branch lines 114a, 114c, 124a and 124c extends from one or two or more main lines 114b, 114d, 124b and 124d to fabricate the anode or cathode. That is, in FIG. 9, in the case of the metal wire constituting the anode, a plurality of branch lines 114a extending from a main line 114b is vertically disposed in parallel, and, in the case of the metal wire constituting the cathode, a plurality of branch lines 124a extending from a main line 124b is horizontally disposed in parallel. In FIG. 10, although similar to FIG. 9, main lines 114d and 124d constitute a closed loop, and a plurality of branch lines 114c and 124c are disposed in parallel in the closed loop. In FIG. 1, each of the metal wires 114 and 124 has a series-connected structure of one strand, and voltage drop occurs at the end thereof. However, as shown in FIGS. 9 and 10, when each of the metal wire 114 and 124 has a parallel-connected structure in which one or more strands of main lines 114b, 114d, 124b and 124d are formed into plural strands of branch lines 114a, 124a, 114c and 124c, the voltage drop does not occur in the branch lines 114a, 124a, 114c and 124c, so that power consumption can be minimized, thereby increasing efficiency.

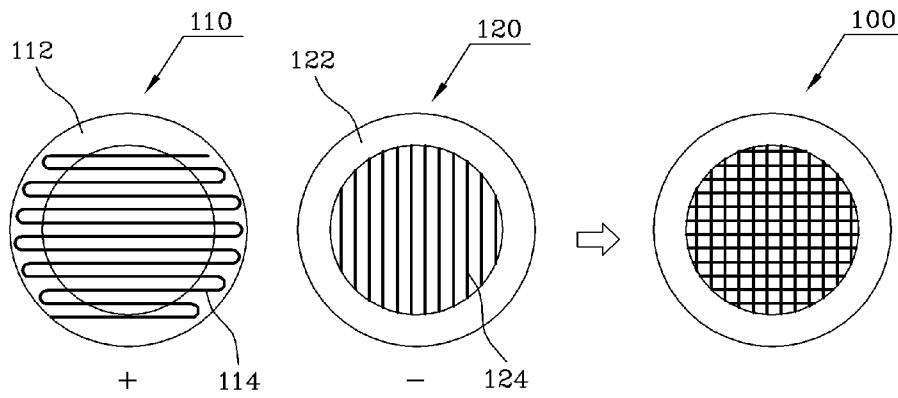
Industrial Applicability

- [61] The grid electrode according to the present invention is used to treat sea water, sewage water, waste water and other water to be treated. Since the grid electrode has a simple structure and satisfies low power consumption, it can be applied to the water treatment of land or sea facilities, and, particularly, can maximize the efficiency of sea water treatment when it is installed in a ballast water flow pipe connected to a ballast tank of a ship or the like. Therefore, it is expected that the grid electrode of the present invention can be widely used in the treatment of land or sea sewage·waste water due to its simple structure, low production cost and high efficiency.

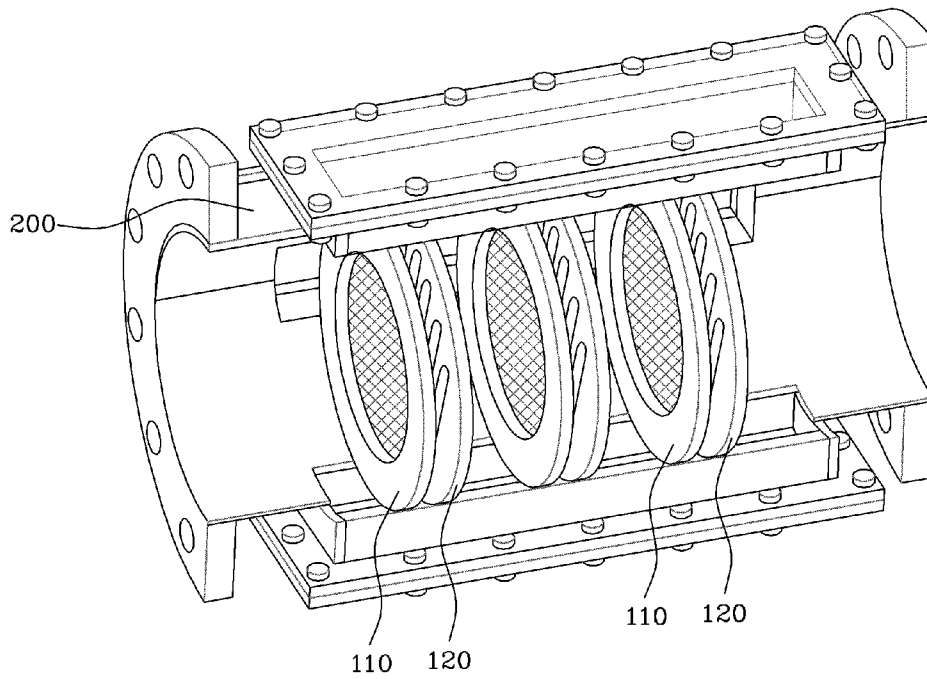
Claims

- [1] A grid electrode for water treatment using a virtual electrode, comprising:
an anode including a conductive metal wire which is vertically extended in a parallel zigzag pattern in a same plane; and
a cathode including a conductive metal wire which is horizontally extended in a parallel zigzag pattern in a same plane,
wherein the anode and cathode are spaced apart from each other such that the metal wire of the anode and the metal wire of the cathode intersect each other.
- [2] The grid electrode for water treatment using a virtual electrode according to claim 1, wherein the anode comprises a first plate-like frame and the conductive metal wire vertically extended in a parallel zigzag pattern and disposed on the first plate-like frame, and the cathode comprises a second plate-like frame and the conductive metal wire horizontally extended in a parallel zigzag pattern and disposed on the second plate-like frame.
- [3] The grid electrode for water treatment using a virtual electrode according to claim 1, wherein each of the conductive metal wires of the anode and cathode comprises at least one main line and a plurality of branch lines extending from the at least one main line parallel thereto.
- [4] The grid electrode for water treatment using a virtual electrode according to claim 1, wherein the conductive metal wire is made of one selected from among nickel (Ni), chromium (Cr), stainless steel, titanium (Ti), iridium (Ir) and alloys thereof.
- [5] A water treatment system, comprising the grid electrode of any one of claims 1 to 4 in a plural number, wherein the plurality of grid electrodes is disposed in series in a ballast water flow pipe of a ship at interval distances, and is connected to a direct-current (DC) power supply.
- [6] The water treatment system according to claim 5, which comprises a microbial fluorometer for measuring a concentration of microbes included in water to be treated and flowing along the ballast water flow pipe, which is disposed at the front, rear or both sides of the plurality of grid electrodes.
- [7] The water treatment system according to claim 5, which comprises a hydrogen gas detector for monitoring a concentration of hydrogen gas produced by electrolysis of water to be treated, which is disposed at a rear of the plurality of grid electrodes.
- [8] The water treatment system according to claim 7, wherein current of the DC power supply is automatically controlled when a concentration of the hydrogen gas detected by the hydrogen gas detector exceeds a predetermined value.

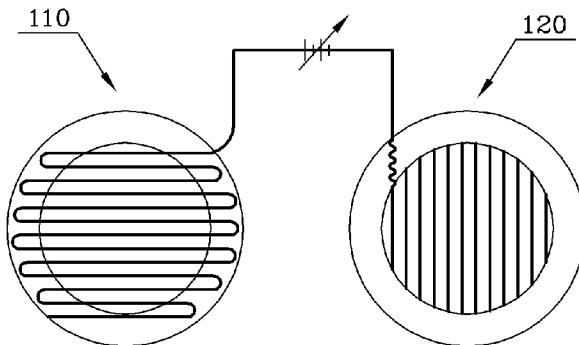
[Fig. 1]



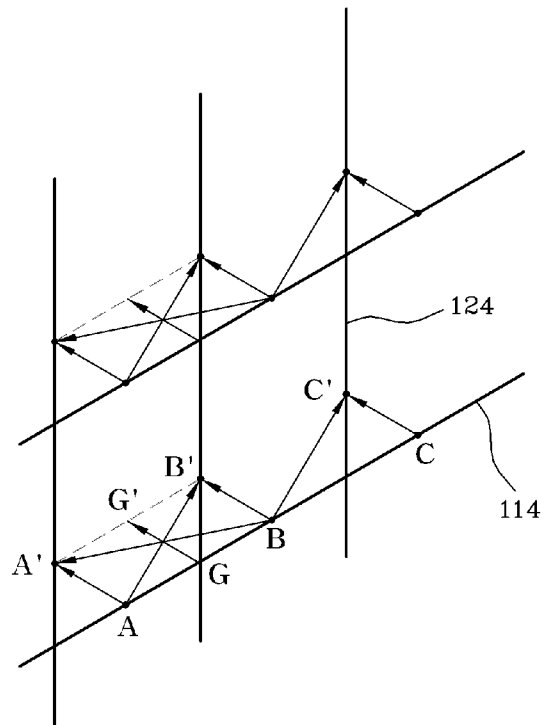
[Fig. 2]



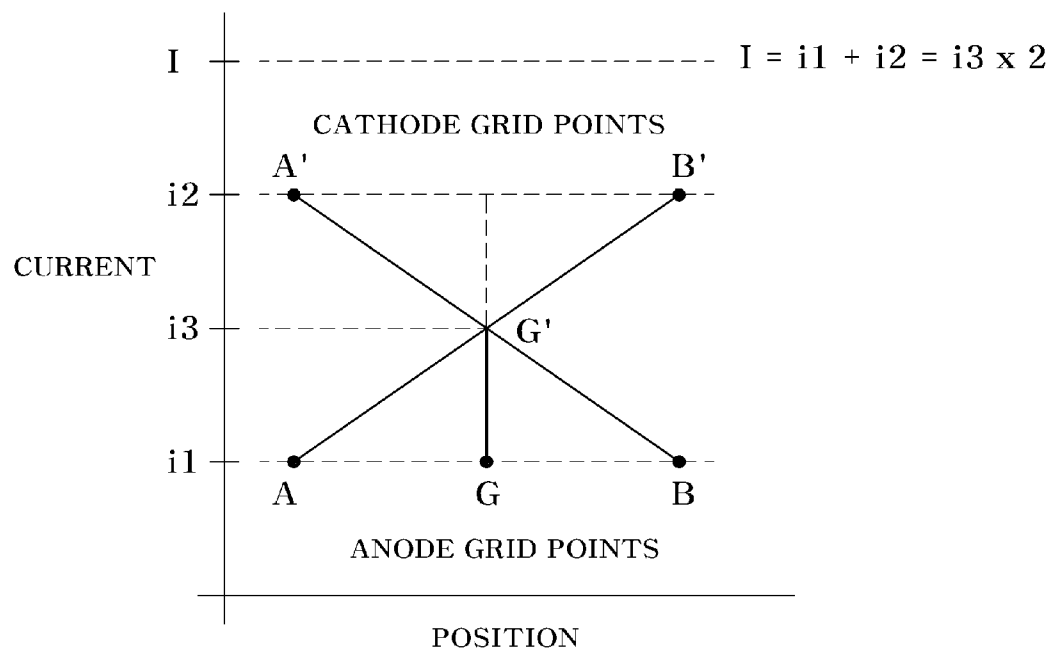
[Fig. 3]



[Fig. 4]

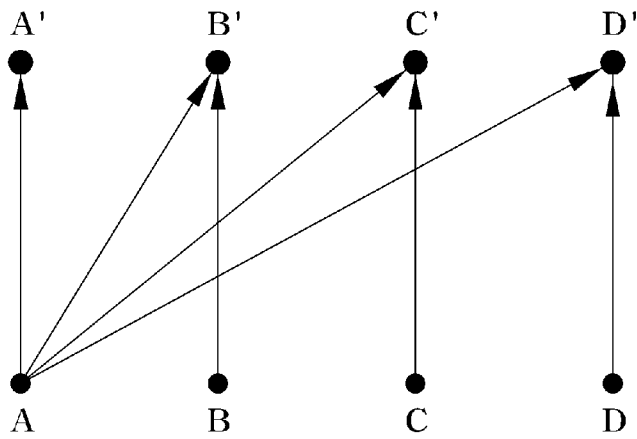


[Fig. 5]



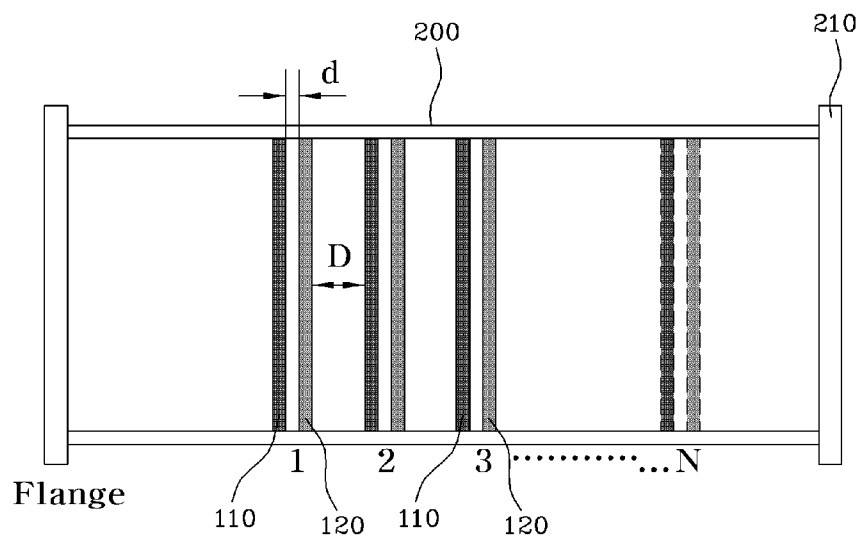
[Fig. 6]

VIRTUAL CATHODE SPOTS

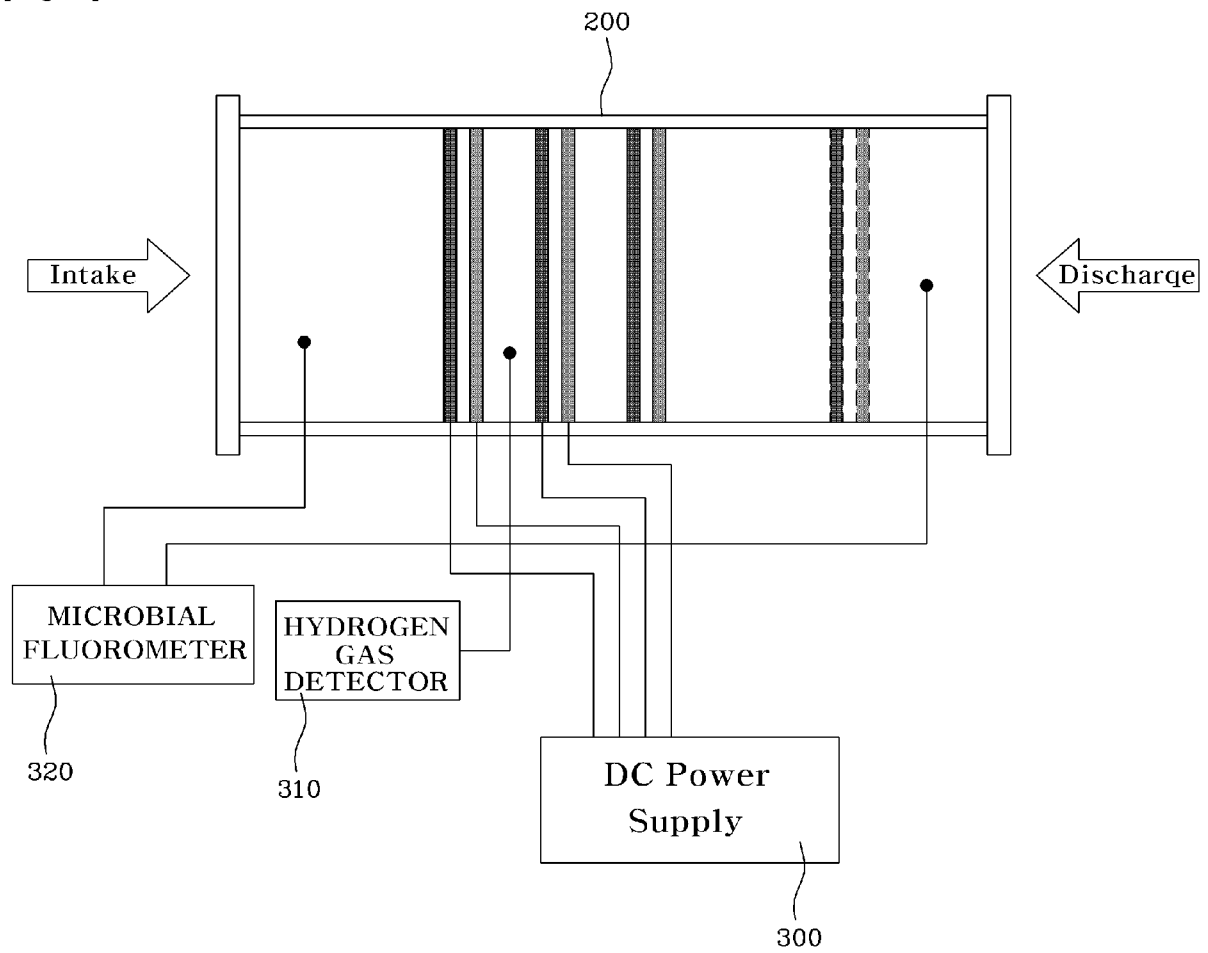


VIRTUAL ANODE SPOTS

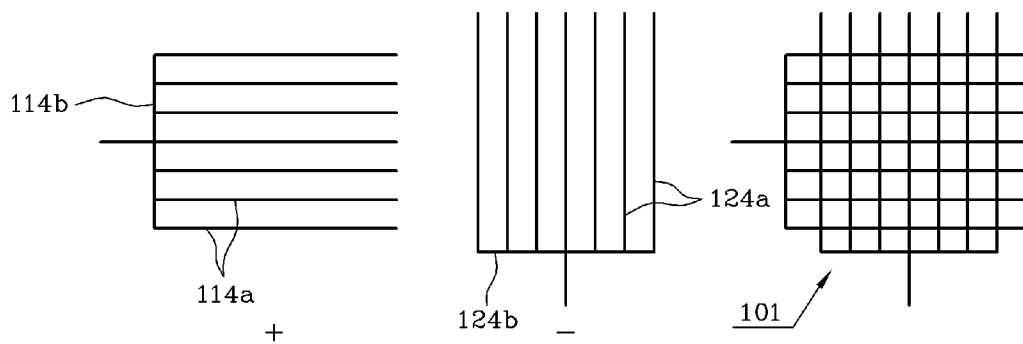
[Fig. 7]



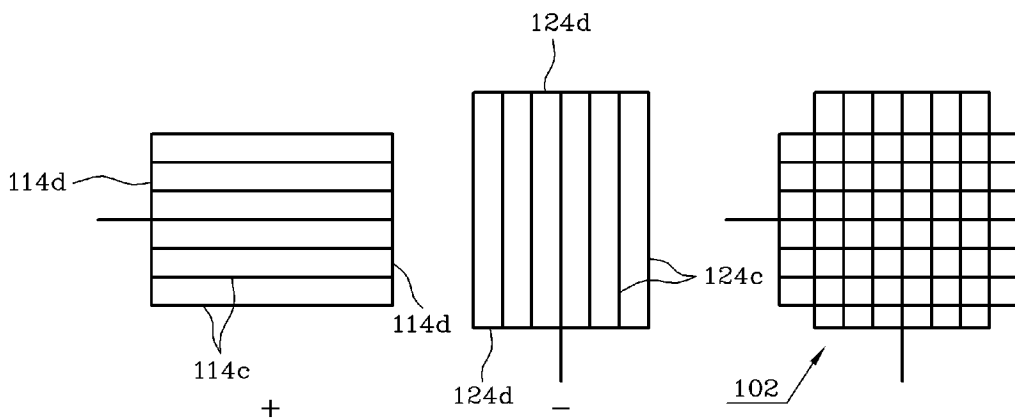
[Fig. 8]



[Fig. 9]



[Fig. 10]



A. CLASSIFICATION OF SUBJECT MATTER***C25B 11/00(2006.01)i***

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 8: C25B 11/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean Utility Models and Applications for Utility Models: IPC as above

Japanese Utility Models and Applications for Utility Models: IPC as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

e-KIPASS (KIPO internal) : "ballast", "electrode", "steril* ", "electrolytic"

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	KR 10-0597254 B1 (E. C. Kim, et al) 28 Jun 2006 See claims 1-14 and Figs 1-8	1-8
A	KR 10-0801185 B1 (D. W. Chung, et al) 29 Jan 2008 See abstract and Figs 1-4	1-8
A	US 2007-0158208 A1 (W.-C. Jung, et al) 12 Jul 2007 See abstract and Figs 5A,5B	1-8
A	KR 2007-0093986 A (F. Randolph, et al) 19 Sep 2007 See abstract and Figs 1, 2	1-8
A	US 2008-0000775 A1 (Harold E. Childers II, et al) 3 Jan 2008 See abstract and Figs 1, 2, 5, 6	1-8



Further documents are listed in the continuation of Box C.



See patent family annex.

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Date of the actual completion of the international search

30 SEPTEMBER 2008 (30.09.2008)

Date of mailing of the international search report

30 SEPTEMBER 2008 (30.09.2008)

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/KR2008/002166

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US 2008-0000775 A1	03.01.2008	NONE	