SPECIFICATION

HIGH ELECTRIC FIELD ELECTROLYSIS CELL

Technical Field

This invention relates to a device and method for electrolyzing water, and more particularly to a High Electric Field Electrolysis (HEFE) cell. In addition, this invention also relates to a device and method for generating electricity using Free Radical Solution water produced by HEFE cells.

Background Art

Electrolysis of water is the technical name for using electricity to split water into its constituent elements, hydrogen and oxygen. The splitting of water is accomplished by passing an electric current through water. The electricity enters the water at the cathode, a negatively charged terminal, passes through the water and exists via the anode, the positively charged terminal. The hydrogen is collected at the cathode and the oxygen is collected at the anode. In an electrolytic cell, the anode is the positive electrode and the cathode the negative (opposite is true for the galvanic cells). The current on the anode is considered a positive current, and that on the cathode is considered negative according to international convention. However, in Electro-analytic chemistry the anodic current is often considered negative, while the cathode current positive.

Electrolysis produces very pure hydrogen for use in the electronics, pharmaceutical and food industries by oxidizing water at the anode according to the following relationship

$$2H_2O \Rightarrow O_2 + 4H^+ + 4e^-$$

And reducing water at the cathode according to the following relationship

$$4H_2O + 4e^- \Rightarrow 2H_2 + 4OH^-.$$

Hence, decomposition of water is a redox process, that is, oxidation reaction occurs at one electrode and reduction reaction at the other.

There are several different types of electrolysis cells in use today that may be used to electrolyze water, including for example Mercury cells, Diaphragm cells, and Membrane cells. In a membrane cell electrolysis, an ion-exchange membrane separates the anode and the cathode compartments. An ion is an electrically charged chemical particle (atoms, molecules or molecule fragment); negatively charged ions are known as "anions" and those with positive charge "cations". The ion exchange membrane is generally a bi-layer membrane placed between the anode and the cathode. It is a plastic sheet formed from ion-exchange resin. An ion-exchange resin is a polymeric resin that contains electrically charged fragments ("fixed ions") permanently attached to the polymer backbone, electrical neutrality is achieved by attached mobile "counter-ions" in the solution phase the resin is immersed into. Therefore, the utility of such membranes is based on their property that they are permeable preferentially only to either positive ions (cation-exchange membrane) or to negative ions (anion-exchange membrane). A practical use of such resin is the removal of

unwanted ions from a solution by replacing them with other ions. For example, a cation exchange resin containing fixed negative charges with attached mobile sodium ions can be used to remove "hardness" from water if the calcium and magnesium ions are more strongly attracted to the resin and therefore will replace the sodium ions. Eventually all the sodium ions will go into solution and the ion-exchange process terminates. The resin can be regenerated by soaking in a high concentration sodium salt solution. Such process can also be used to remove unwanted ions from polluted water streams.

All prior art electrolysis cells have insufficiently sized cylindrical ion exchange membranes with improper electrode positioning. The sizes of the cells are not adequate for increased production of electrolyzed water. In addition, due to their unique physical characteristics, it is difficult to control water flow around ion exchange membranes and electrodes of prior art electrolysis cells. Furthermore, drain water generated at cation (+) side is in general equal to or at least quarter as much as the ozone water generated at the anion (-) side. The prior art electrolysis cells also produce unwanted ozone gas.

Disclosure of Invention

The present invention seeks to provide a High Electric Field Electrolysis cell for electrolyzing water to transform it into Free Radical Solution (FRS) water for cleaning, deodorizing, and sterilizing.

The present invention further seeks to provide a High Electric Field Electrolysis cell for electrolyzing water to produce FRS water for use for generation of electric energy.

In addition, the present invention seeks to provide a High Electric Field Electrolysis cell whose dimensions and output volume of FRS water may readily be varied.

In keeping with the principles of the present invention, unique High Electric Field Electrolysis (HEFE) cell is presented that overcomes the short falls of the prior art electrolysis cells. The HEFE cell of the present invention is comprised of a pair of flat electrodes attached (or coated) onto a flat proton ion exchange membrane enclosed in a corresponding cell structure that accommodates the electrodes and the proton ion exchange membrane. The electrolysis cell structure is comprised of at least one inlet channel for receiving purified water and two outlet channels for output of electrolyzed FRS water and hydrogen rich water. The High Electric Field Electrolysis cell of the present invention further provides a mechanism for recycling of hydrogen rich water for re-use or electric power generation.

These and other objects, features, aspects, and advantages of the invention will be apparent to those skilled in the art from the following detailed description of preferred non-limiting embodiments, taken together with the drawings and the claims that follow.

Brief Description of Drawings

It is to be understood that the drawings are to be used for the purposes of illustration only and not as a definition of the limits of the invention.

Referring to the drawings in which like reference numbers present corresponding parts throughout:

Fig. 1 is a typical schematic illustration of a High Electric Field Electrolysis cell, in accordance with the present invention;

Fig. 2 illustrates the detailed layered structure of an electrode in relations to other components within the High Electric Field Electrolysis cell illustrated in Fig. 1;

Fig. 3 illustrates one embodiment for degassing of hydrogen rich water, in accordance with the present invention;

Fig. 4 illustrates another embodiment for degassing of hydrogen rich water, in accordance with the present invention;

Fig. 5 illustrates the principles used to generate electricity using the High Electric Field Electrolysis cell, in accordance with the present invention;

Fig. 6 is schematic diagram of a control circuit for supply of power to High Electric Field Electrolysis cell, in accordance with the present invention.

Fig. 7 illustrates a typical embodiment for connecting multiple cells in series, in accordance with the present invention.

Fig. 8 illustrates a typical layered structure of multiple cells in one unit, in accordance with the present invention.

Fig. 9 is a sample chart for ORP measurements of FRS produced through double cells process.

Best Mode for Carrying Our the Invention

Fig. 1 is a typical schematic illustration of a High Electric Field Electrolysis (HEFE) cell 10 of the present invention. As illustrated, HEFE cell 10 is a flat structure with dimensions that may be changed to appropriately accommodate its installation in any area or meet production requirements with respect to volume of FRS water generated. Treated water (purified or soft water) flows into the HEFE cell 10 through the inlet channel 2 and electrolyzed Free Radical Solution water flows out of the HEFE cell through a first outlet channel 4 with rich hydrogen water drained through a second outlet channel 6. Upon treated water's entry through the inlet channel 2, the proton ion exchange membrane 8 inside the HEFE cell 10 partitions off the incoming water. The proton ion exchange membrane 8 of the present invention is in general flat and made of solid polyelectrolyte with a thickness of about 10μm~500μm. Soft or purified water is recommended for use with the HEFE cell because calcium and magnesium ions found in most hard (or regular) water are not as permeable and tend to block the porous surface of the proton ion exchange membrane 8, deteriorating its performance.

Attached (or coated) to one side of the ion exchange membrane 8 is mesh (or net) type anode electrode (+) 16 that attracts anions (-), and attached (or coated) to the other side of the ion exchange membrane 8 is the mesh (or net) type cathode (-) electrode 14 that attracts cations (+). The electrodes 14, 16 are comprised of plurality of holes or open spaces between the cords or wires of the mesh (or net) for intake of water into the proton ion

exchange membrane 8. Upon application of electric power (of approximately 5 volts V to 20V) to the anode (+) electrode 16 and the cathode (-) electrode 14, an electric current (a stream of electrons) passes through water, splitting water molecules into positive and negative ions on and/or near the anode (+) electrode. The positive hydrogen cations (+) migrate towards the cathode (-) electrode 14 and combine with an electron to form a hydrogen atom. The two hydrogen atoms combine to make a hydrogen molecule H_2 near the cathode (-) electrode 14, generating hydrogen rich water that is drained through the outlet channel 6. The hydroxide ions (anions (-)) such as O_2^- or OH^- radicals move toward the anode (+) electrode 16, lose some electrons and a proton to form oxygen atoms and other Free Radicals, and are removed through a second outlet channel 4 as FRS water. In general, water flow at positively charged anode (+) electrode 16 (the anion (-) side) is less than 1/10 of water flow at negatively charged cathode (-) electrode 14 (at the cation (+) side). The electrolysis cell generates free radicals such as hydroxyl radical, superoxide anion, singlet oxygen, perhydroxy radical, hydroxyl ion, hydroperoxy radical, hydrogen peroxide, ozone and active oxygen.

Fig. 2 illustrates the detailed layered structure of the electrodes 14 and 16, in addition to other components used in the High Electric Field Electrolysis cell 10. In general, electrodes 14, 16 are coated by or made from platinum or other noble (or precious) metals, and are placed between the proton ion exchange membrane 8 and the commuting guide 20. The commuting guide 20 is typically made of acrylic resin; however, it may be replaced with other appropriate materials such as stainless steel or titanium. The electrodes 14,

16 may be fixed and attached to the proton ion exchange membrane 8 by a pressed attachment mechanism (not illustrated) or simply coated onto the proton ion exchange membrane 8. Although for simplicity only the cathode (-) electrode 14 is illustrated in Fig. 2, it should be understood that similar arrangement is made for placement of the anode (+) electrode 16 in relations to the proton ion exchange membrane 8 and commuting guide 20. Furthermore, the description with respect to the structure of the cathode (-) electrode 14 illustrated herein Fig. 2 also applies to the anode (+) electrode 16. As illustrated in the cross sectional view A - A' in Fig. 2, each mesh electrode 14, 16 of the present invention is comprised of rough, non-smooth texture layers 22, 26 that generate turbulence in the flow of water at or near the ion exchange membrane 8. The first rough texture layer is comprised of very small (or fine) protrusions 22, with the other having comparatively rough (or larger) protuberances 26. The smaller protrusion mesh layer 22 of each electrode faces and attaches to the proton ion exchange membrane 8, with the larger protuberance mesh layer side 26 facing the water flow, juxtaposed away from the ion exchange membrane 8. Upon water flow, both the larger and the smaller protuberance mesh layers 26, 22 create a disorderly turbulence of water as illustrated by the small arrows, forcing water into the proton ion exchange membrane 8. The rougher (or larger protrusion) texture mesh layer 26 directly facing the water flow is in "the way" of this flow, creating maximum turbulence in the flow of water. This structure promotes disorderly flows at or near the proton ion exchange membrane surface, improving the efficiency of fresh water intake into it. In addition, the turbulent

flow of water intake also allows extra oxygen into the membrane 8, improving the efficiency of the electrolysis by increasing water's Dissolved Oxygen (DO) levels, which in turn improve Oxidation Reduction Potential (ORP) level of water.

Figs. 3 and 4 illustrate the degassing of hydrogen gas from the cathode electrode (-) side 14 of the HEFE cell 10 where cations (+) such as hydrogen accumulate. The immediate degassing of hydrogen improves Oxidation Reduction Potential of draining water output from the outlet channel 6, allowing this water to be recycled to inlet channel 2 (shown in Fig. 1) for reuse. The transfer of hydrogen rich water from outlet channel 6 to the inlet channel 2 may be done by a variety of mechanisms, including some type of tubing or piping mechanisms comprised of appropriate materials such as plastic, metallic, stainless copper or other materials connecting the drain water outlet channel 6 to the inlet channel 2. Well known hydrogen-degassing mechanism such a vacuum pump (not illustrated) may be used to reduce the pressure in the area 30, facilitating the removal of hydrogen gas. The embodiment illustrated in Fig. 3 also show the use of well known gas transmission or gas-liquid separation membrane 36 which further help in the degassing of hydrogen from the water before it is drained through the outlet channel 6 for further recycling. Other known degassing mechanism include the use of closed chambers for degassing of hydrogen.

Fig. 4 illustrates a second embodiment of hydrogen degassing in accordance with the present invention. With this embodiment, the cathode (-) electrode 14 (or the cation (+) side) is open to outside atmosphere where

hydrogen gases simply evaporate from water to outside air. With this embodiment, the water level 38 is controlled to prevent overflow. At the cathode (-) electrode 14, cations (+) such as hydrogen molecules are generated and hydrogen gas is floated in water. Water may be used to wash the hydrogen gas and other faint matters such as sodium that penetrate through the small openings of the proton ion exchange membrane 8.

The following is a listing of Free Radicals and their transformation patterns in FRS water output at the outlet channel 4. Transformation patterns illustrated below occur repeatedly at random both during and after the electrolysis process. Each Free Radical is a result of the transformation of H_2O water molecules in FRS water, illustrating the difference between FRS water and regular water (where no H_2O molecule transformation occurs).

Transformation Pattern:	Free Radical Generated:
$2H_2O \longrightarrow O_2 + 4H^+ + 4e^-$	Oxygen
$3H_2O \longrightarrow O_3 + 6H^+ + 6e^-$	Ozone
$2H_2O \longrightarrow H_2O_2 + 2H^+ + 2e^-$	Hydrogen Peroxide
$2H_2O \longrightarrow {}^*O_2^- + 4H^+ + 3e^-$	Super Oxide Anion
$H_2O \longrightarrow HO^* + H^+ + e^-$	Hydroxyl Radical
$2H_2O \longrightarrow 2O + 4H^+ + 4e^- \longrightarrow 2H_2 + {}^1O_2$	Singlet Oxygen
${}^*O_2^- + H^+ \longrightarrow {}^*O_2H$	Perhydroxy Radical
$HO^* + H_2O + e^- \longrightarrow H_3O_2^-$	Hydroxyl Ion
${}^*O_2^- + H^+ \longrightarrow HOO$ or HO_2^*	Hydroperoxy Radical

The generation of Free Radicals is random and is not necessarily in the sequence listed. The Free Radicals are transformed from one to another

instantly and frequently in a random manner. Super oxide anion and hydroxyl radical float as free radicals in FRS water and are eventually stabilized by transforming to ozone or hydrogen peroxide. Furthermore, hydrogen peroxide and ozone also continue their transformations after electrolysis in the following manner:

$H_2O_2 \longrightarrow H^+ + HO_2^-$ (Transformation of hydrogen peroxide)

$O_3 + HO_2 \longrightarrow HO^* + O_2^- + O_2$ (Transformation of Ozone)

Free Radicals generated are very unstable and tend to combine with other molecules or atoms surrounding them to stabilize. This phenomenon is used to sterilize various infective bacterial diseases such as for example, pathogenic bacilli. Application of FRS water to an infected area causes the Free Radicals in FRS water to combine with bacteria and other molecules, sterilizing the infected region. When water is electrolyzed, oxygen is forcefully removed from H_2O water molecules, and is transformed into one of unstable Free Radical atoms that tends to combine with other atoms or molecules surrounding it. The combinations of Free Radicals such as oxygen with other molecules, such as pathogenic bacilli oxidize and sterilize the bacteria. All the transformation patterns of Free Radicals are random, continuous and repeat at almost the same level for at least two -(2) hours after electrolysis. Therefore, FRS water can be used as a sterilizing solution for two- (2) hours after production, which is a substantial practical benefit for use in comparison with the existing electrolysis water such as for example, Ultra Acidic Water. The ORP levels for Ultra Acidic Water is reduced immediately after

production, which means a loss in sterilizing capability. Specifically, the Ultra Acidic Water can maintain a 900mV ORP for only 10 ~ 15 minutes after production. The ORP level of the FRS water of the present invention will reach its peak ORP usually 10 ~ 15 minutes after production and maintain more than 900mV level at least 2 hours thereafter, including the very high free radical reactions.

HEFE cell can be used as a source of electric energy such as a battery. Fig. 5 illustrates the principles used to generate electricity using a HEFE cell. Instead of allowing hydrogen gasses to be removed from water or evaporated, as illustrated in Figs. 3 and 4, the hydrogen rich water at the cathode (-) electrode side 14 may be recycled and moved to the anode (+) electrode side 16 and oxygen rich water at the anode (+) electrode 16 moved to the cathode (-) side 14. Due to FRS water's very high ORP level of more than 900mV, the H_2 hydrogen molecules 42 at the cathode (-) electrode side 16 will release their electron and transform into positively charged cation (+) molecules of the form $2H^+$. The electron released may be captured and moved to a load 40, thereby generating electric power for this load. The electrons from the load 40 are than returned through a closed electrical return path to combine with oxygen 44 and hydrogen ions $2H^+$, forming water 46. The transformation of molecules at each electrode is as follows:

At the Cathode (-): $2H_2 \Rightarrow 4H^+ + 4e^-$

At the Anode (+): $4e^- + 4H^+ + O_2 \Rightarrow 2H_2O$

$e^- + H^+ + -OH \rightarrow H_2O_2$

$2e^- + 2H^+ + H_2O_2 \rightarrow 2H_2O$

$$6e^- + 6H^+ + O_3 \rightarrow 3H_2O$$

With a mechanism to add oxygen gas to the FRS water at the cation (+) side, the efficiency of the entire system will increase to a point where most recycled hydrogen rich water may than be used at the anion (-) side to generate electricity. The above process may be improved by concatenating at least two HEFE cells to one another. For example, a primary HEFE cell may be connected to a secondary HEFE cell, where FRS water is generated effectively through the first HEFE cell, and electricity through the second HEFE cell.

Fig. 6 is schematic diagram of a control circuit for supply of power to HEFE cell 10. The power supplied to the HEFE cell 10 may be activated by a switching power supply 60, which in turn activates a Pulse Width Modulation (PWM) amplifier 62, powering the HEFE cell 10. The power supplied to the electrodes 14 and 16 of HEFE cell 10 create an electric field therein to electrolyze the water to generate FRS water. The supplied voltage to the HEFE cell 10 is controlled by a control circuit 74 that acts to shut-off or maintain power to the HEFE cell 10 based on information received from various sensors 66 to 72. The Oxidation-Reduction Potential (ORP) sensor 66 measures the amount of ORP level of FRS water. If the ORP level increases to more than 1200mV or decreases below the 700mV, the control circuit 74 will shut-off the PWM amplifier 62 to thereby shut-off power to the HEFE cell electrodes 14 and 16. The pH sensor 68 measures the Hydrogen Ion Concentration (HIC) level of FRS water to maintain it between 6 to 8 pH. The flow sensor 70 and the temperature sensor 72 measure the amount (or

quantity) of water flow and its temperature, respectively. If water flow decreases to less than 10% of a predetermined threshold water flow rates the control circuit 74 will shut-off the PWM amplifier 62 and control the flow valve 80. An increase in water temperature over 45 degrees in Celsius will trigger a shut-off of power by the control circuit 74. The resulting sensed information may be seen by a LED display 76 that may comprise of LEDs or other mechanisms such as LCDs or others, controlled by the control circuit 74.

Other factors (or occurrences) that may trigger a shut-off by the control circuit 74 may include an overcurrent (a current flow of above $10A/cm^2$ per cell), an overvoltage (an increase voltage of over 20V per cell) or by means of a human interface 78. The maximum allowable power supplied to the HEFE cell should be in a range of 120V +/- 20%p, with a maximum allowable electric leakage of 15mA. Any deviation from the threshold levels of these parameters indicated herein may trigger a shut-off of power to HEFE cell 10 by the control circuit 74. Various sensors including for example current, voltage, and power sensors are used to detect such occurrences. These sensors may be an integral part of the control circuit 74.

HEFE Cell can gain higher performance of electrolysis by connecting multiple cells in series. Fig.7 illustrates a typical embodiment for connecting multiple cells in series. In this embodiment shown in Fig.7, two cells are connected. The first cell (No.1 cell) increases the ORP of FRS and, then, the second cell (No.2 cell) enhances the ORP to even higher level. The enhanced performance is varied depends on the operating circumstances such as quality of tap water. Fig.8 illustrates a typical layered structure of multiple cells

in one unit. In this embodiment shown in Fig.8, there are two cells in one unit. Cathode (-) electrode is one flat layer but Anode (+) electrode is separated into two peaces. The separated Anode (+) electrodes work independently. Fig. 9 is a sample chart for ORP measurements of FRS produced through double cells process. This chart also shows the relations of ORP of FRS vs. electric currents given on No.1 cell and No.2 cell. ORP can be delicately adjusted and controlled by various combinations of given electric currents on each cell.

While illustrative embodiments of the invention have been described, numerous variations and alternative embodiments will occur to those skilled in the art. For example, the protrusions shown as two layer circular (or spherical) protuberances for the electrodes need not be spherical nor do they have to be arranged as symmetrical rows as shown. Any means that may create the maximum turbulence in water flow near or adjacent the ion exchange membrane will work. The number of inlet and outlet channels may be varied. For example, three outlet channels may be used, one to output FRS water, the second to output rich hydrogen water, and third to output degassed hydrogen water. The rich hydrogen water may be re-used for generation of electricity and the degassed hydrogen water recycled back to the inlet channel. The physical structure of the HEFE cell need not be a rectangular-cube as illustrated. It may comprise of rounded edges. Other sensors may also be used in addition to the ones described. These may include pressure sensors to detect the atmospheric pressure to optimize and maintain a maximum level of dissolved oxygen in FRS water. Such variations

and alternate embodiments are contemplated, and can be made without departing from the spirit and the scope of the invention and the appended claims.

CLAIMS

1. A electrolysis cell, *comprising*:

a structure having at least one inlet channel for intake of water, a first outlet channel for output of hydrogen rich water, and a second outlet channel for output of Free Radical Solution water;

said structure accommodates a flat proton ion exchange membrane placed in between two flat mesh electrodes;

application of power to said electrodes electrolyzes water flowing through said inlet channel, generating Free Radical Solution water output through said first outlet channel and hydrogen rich water output through said second outlet channel.

2. The electrolysis cell of Claim 1, wherein each of said flat mesh electrodes is comprised of two layers with a first layer having large protuberances and a second layer having smaller protuberances compared with said first layer's larger protuberances.

3. The electrolysis cell of Claim 2, wherein said first layer with large protuberances is juxtaposed distal away from the proton ion exchange membrane surface, creating turbulence in flow of water adjacent said proton ion exchange membrane.

4. The electrolysis cell of Claim 2, wherein said second layer with smaller protuberances is juxtaposed facing the proton ion exchanged membrane.

5. The electrolysis cell of Claim 1, wherein said hydrogen rich water output through said second outlet channel is degassed for re-use.

6. The electrolysis cell of Claim 5, wherein said degassing of said hydrogen rich water produces hydrogen and water, with said hydrogen used for generation of electric power and said water recycled back to said electrolysis cell through said inlet channel.

7. The electrolysis cell of Claim 1, wherein power to said electrolysis is controlled by a control circuit.

8. The electrolysis cell of Claim 7, wherein said control circuit adjusts inlet water flow and/or electric power to maintain the most effective production of FRS water and hydrogen rich water, or triggers a power shut-off signal to shut power off to said electrodes of said electrolysis cell based on information signals from a plurality of sensors that detect a variety of parameter values and output sensed signals based on deviation of normal parameter values from pre-programmed threshold levels.