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(54) **Title:** AN APPARATUS AND METHOD FOR ELECTROCHEMICAL PRODUCTION OF OXIDANT RELATED COMPOUNDS

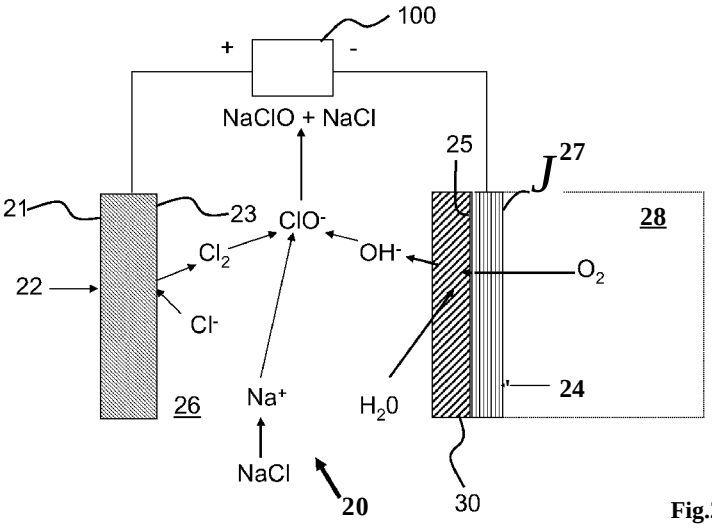


Fig.2

(57) **Abstract:** The present disclosure describes an electrochemical cell that has an electric power source, an anode, a gas diffusion cathode and a gas space in communication with the gas diffusion cathode. The gas diffusion cathode includes an ion exchange coating that faces the anode. The ion exchange coating is a polymer that also protects the gas diffusion cathode. **A** feed solution flows between the ion exchange coating and the anode. The gas space contains at least some oxygen gas that diffuses into the gas diffusion cathode. Within the gas diffusion cathode oxygen reacts to produce hydroxide radicals. The anion exchange coating transports the hydroxide radicals from the gas diffusion cathode to electrochemically produce oxidant-based biocides.

AN APPARATUS AND METHOD FOR ELECTROCHEMICAL PRODUCTION OF OXIDANT RELATED COMPOUNDS

FIELD

[0001] The present disclosure relates generally to the production of oxidant-based chemicals and in particular to the electrochemical production of oxidant-based biocides.

BACKGROUND

[0002] The following discussion is not an admission that anything discussed below is citable as prior art or common general knowledge.

[0003] Oxidant-based biocides are an established treatment used to control the levels of the microorganisms within industrial water circulation systems. Depending upon the specifications of the industrial water circulation system, oxidant-based biocidal treatment programs can include a continuous maintenance dose, an intermittent maintenance dose or periodic high doses. Therefore, operators typically require large supplies of oxidant-based biocides at all times for biocidal maintenance regimes and to address any microbial outbreaks.

[0004] Sodium hypochlorite (NaClO) is one example of an oxidant-based biocide. Sodium hypochlorite is produced by chloralkali processes, such as membrane based processes that take place in electrochemical cells. The electrochemical cells include at least one anode and one cathode with a membrane that is selectively permeable to positively charged cations. The cation permeable membrane separates the electrochemical cell into an anolyte chamber and catholyte chamber. A solution of sodium chloride is introduced into the anolyte chamber where negatively charged chlorine ions undergo an oxidation reaction to form chlorine gas:

$$2Cl^- \rightarrow Cl_2 + 2e^- \quad (1).$$

Water is introduced to the catholyte chamber where it is reduced to hydrogen gas and hydroxide ions at the cathode:

$$2H_2O + 2e^- \rightarrow H_2 + 2OH^- \quad (2).$$

The positively charged sodium ions pass through the cation permeable membrane to react with the hydroxide ions to produce sodium hydroxide in the overall reaction of:

$$2NaCl + 2H_2O \rightarrow Cl_2 + H_2 + 2NaOH \quad (3).$$

[0005] The chlorine gas and the sodium hydroxide can be mixed under controlled conditions to produce sodium hypochlorite.

[0006] Membrane-based chloralkali manufacturing exhibits a direct relationship between the voltage, also referred to as the working potential, applied to the electrochemical cell and the production of chloralkali products. Due to this relationship and the high demand for chloralkali products, the chloralkali manufacturing industry is a very large consumer of electricity. Therefore, there is a need for improved energy consumption in chloralkali manufacturing processes.

[0007] One approach to improve the energy consumption of the membrane- based chloralkali process is the use of a gas diffusion membrane electrolysis cell 10, shown in Figure 1. The gas diffusion membrane electrolysis cell 10 includes an electric power source 100, an anode 12, a gas diffusion cathode 14 and a cation permeable membrane 18. The cation permeable membrane 18 separates the feed space into an anolyte chamber 16A and a catholyte chamber 16B. The gas diffusion cathode 14 is permeable to gas, such as oxygen, which reacts with the reduced water to produce hydroxide radicals in the catholyte chamber 16B. A sodium chloride solution is introduced into the anolyte chamber 16A and the negatively charged chlorine ions are oxidized to form chlorine gas, while the positively charged sodium ions cross the cation permeable membrane 18 to form sodium hydroxide.

SUMMARY OF THE INVENTION

[0008] A gas diffusion membrane electrochemical cell demonstrates improved energy consumption in comparison to a non-gas diffusion membrane-based electrolysis cell operating at the same current density. However, the gas diffusion membrane electrolysis cell still requires the use of costly cation permeable membranes that can be subject to fouling, which impedes efficiency and increases maintenance and capital replacement costs.

[0009] An electrochemical cell for the production of oxidant-based biocides is described in the detailed description below. The electrochemical cell comprises an electric power supply, an anode spaced from a gas diffusion cathode and a plenum adapted to receive gas. The gas diffusion cathode includes an ion exchange coating on the surface that faces the anode. The plenum communicates with the gas diffusion cathode.

[001 0] In operation, a concentrated feed solution is introduced into the feed space that is between the gas diffusion cathode and the anode of the electrochemical cell. At the gas diffusion cathode, oxygen from the plenum enters the gas diffusion cathode. Within the gas diffusion cathode, the oxygen is reduced to produce hydroxide radicals. The hydroxide radicals are transported by the ion exchange coating to react within the feed space to produce an oxidant-based biocide.

[001 1] The ion exchange coating has properties that provide protection of the gas diffusion electrode. The protection includes physical protection of a high surface area region within the gas diffusion cathode. This physical protection permits flow rates that are higher than those used in a typical membrane based, gas diffusion electrochemical cell. Higher flow rates of the feed solution may increase the current efficiency and productivity of the electrochemical cell. The ion exchange coating also provides chemical protection by preventing chemical reactions that can degrade the high surface area region within the gas diffusion cathode. Additionally, the ion exchange coating transports the hydroxide ions from within the gas diffusion cathode to react within the feed space. Without being bound by theory, this transport decreases the resistance of the gas diffusion cathode in comparison to a gas diffusion cathode that merely relies upon diffusion as the mechanism to transport the hydroxide ions out of the gas diffusion cathode. In this manner, the resistance at the gas diffusion cathode is decreased and the working potential requirements of the electrochemical cell are also decreased.

BRIEF DESCRIPTION OF THE DRAWINGS

[001 2] Figure 1 is a cross-sectional schematic drawing of a prior art gas diffusion membrane process.

[001 3] Figure 2 is a cross-sectional schematic drawing of an electrochemical cell for the production of oxidant-based biocides.

[0014] Figure 3 is a schematic drawing of a water treatment system.

[0015] Figures 4A, 4B, 4C and 4D are line graphs depicting the experimental productivity (g/day) results from four concentrations of feed solution processed by the electrochemical cell of Figure 2.

[0016] Figure 5A, 5B, 5C and 5D are line graphs depicting the experimental current efficiency (%) results from four concentrations of feed solution processed by the electrochemical cell of Figure 2.

[0017] Figure 6A, 6B, 6C and 6D are line graphs depicting the experimental energy consumption (kWh/kg) results from four concentrations of feed solution processed by the electrochemical cell of Figure 2.

[0018] Figure 7 is a line graph depicting the experimental productivity (g/day) results from two electrochemical cells running in series.

[0019] Figure 8 is two line graphs representing the relationship between current and the open circuit voltage, over time, when current is applied to a control electrode and an ion exchange coated electrode.

DETAILED DESCRIPTION

[0020] An electrochemical cell for the production of oxidant-based biocides comprises an electric power source, an anode, a gas diffusion cathode and a plenum of gas. The gas diffusion cathode includes an ion exchange coating on the surface that faces the anode. The plenum of gas is in communication with the gas diffusion cathode.

[0021] Figure 2 depicts an electrochemical cell 20 for the production of oxidant-based biocides. The electrochemical cell 20 comprises an electric power source 100, a feed space 26, a gas space 28, an anode 22 and a gas diffusion cathode 24.

[0022] The electric power source 100 is a DC source of electric current that flows through an electrolytic circuit. The electrolytic circuit is complete when an electrolyte containing fluid is present in the feed space 26. The ions within the electrolytic fluid transfer the electric current between the anode 22 and the gas diffusion cathode 24. Optionally, the source of electric power supply can be an AC power source.

[0023] The feed space 26 is positioned between the anode 22 and the gas diffusion cathode 24. The feed space 26 is adapted to receive a feed solution that contains dissociated anions and cations. For example, the feed solution can be a sodium chloride solution that contains dissociated chloride anions and sodium cations. The feed space 26 does not require a selectively permeable membrane.

[0024] The gas space 28 is a plenum in fluid communication with the gas diffusion electrode 24. The gas space 28 is adapted to receive and transfer a gas that has at least some oxygen, for example pure oxygen gas or a gas mixture that contains at least some oxygen, such as air.

[0025] The anode 22 comprises an electrode substrate composed, for example, of titanium or a titanium alloy. The anode 22 may be generally planar in shape with a first anode side 21 and a second anode side 23. The second anode side 23 is in fluid communication with the feed space 26. When the electrolytic circuit is complete, the anode oxidizes the chlorine anions from the sodium chloride solution to produce chloride gas and electrons:

$$2Cl^- \rightarrow Cl_2 + 2e^- \quad (1)$$

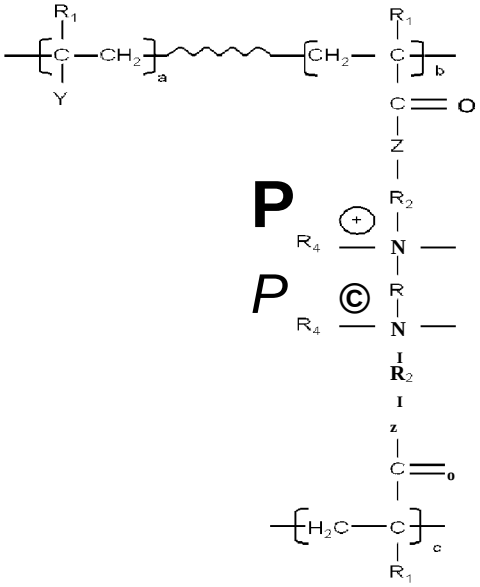
[0026] The gas diffusion cathode 24 may be generally planar in shape, with a first cathode side 25 and a second cathode side 27. The first cathode side 25 is in fluid communication with the feed space 26 and the second cathode side 27 is in fluid communication with the gas space 28. The gas diffusion cathode 24 has a current collector (not shown) comprising, for example, a titanium mesh. The current collector conducts the electric current from the electric power source 100 through to the reacting part of the gas diffusion cathode 24. The reacting part of the gas diffusion cathode 24 may be a high surface area, activated carbon substrate located between the first cathode side 25 and the second cathode side 27.

[0027] The first cathode side 25 is water permeable to allow water to enter into the activated carbon substrate from the feed space 26. The second cathode side 27 is permeable to gas which allows gas to enter the activated carbon substrate from the gas space 28. Inside the activated carbon substrate of the gas diffusion cathode 24, the oxygen gas reacts with the liquid water in a four electron reduction reaction:

$$2H_20 + 0_2 + 4e^- \rightarrow 40H^- \quad (4).$$

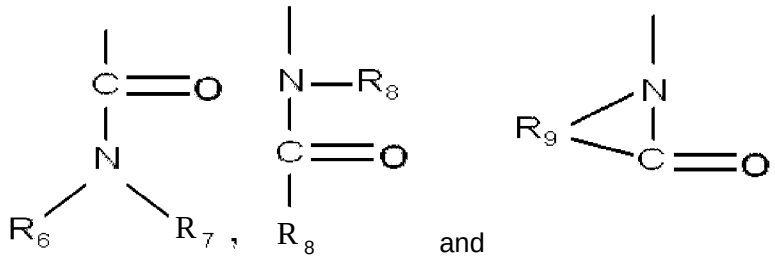
[0028] The hydroxide ions produced by the four electron reduction reaction move from the solid phase of the gas diffusion cathode 24 to the feed space 26 through an ion exchange coating 30. The ion exchange coating 30 is positioned on the first cathode side 25. The ion exchange coating 30 is composed of an insoluble, and optionally gas impermeable, cross-linked polymer that has ion exchange properties. The polymer can be stable in the presence of strong oxidants (such as chlorine, hydrogen peroxide, ozone, hypochlorite species, and the like), or other chemicals such as caustics (such as sodium hydroxide, potassium hydroxide, and the like). In one option, the polymer is stable in both oxidants and caustics. For the purposes of this disclosure, the term "stable" refers to the polymer not reacting, such as degrading, decomposing, corroding or otherwise, in the presence of strong oxidants and/or caustics under normal operational conditions throughout a useful lifespan. By not reacting in this manner, the polymer maintains the ion exchange properties, and other useful properties, through the practical life span of the gas diffusion cathode 24.

[0029] The polymer can be acrylamide based or acrylic based. For example, the polymer described in U.S. 7,968,663 to MacDonald *et al.,* the disclosure of which is hereby incorporated into this application by reference, is an anion exchange polymer of the formula:



wherein R is -[CH_2 - $CH(OH)]_2$-W; R_1 is hydrogen or a C_1-C_{12} alkyl group; a is from about 0 to about 0.75, b and c are each independently, from about 0.25 to about 1.0; Z

is oxygen or N-R_3; R_2 is -[CH_2]„-; R_3 is hydrogen or -[CH_2]$_m$-CH_3; R_4 and R_5 are each, independently, -[CH_2]$_m$-CH_3; X is selected from the group consisting of Cl, Br, I and acetate; W is a bridging group or atom; m is an integer from 0 to 20; n is an integer from 1 to 20; and Y is selected from the group consisting of



and

wherein R_6, R_7 and R_8 are each, independently, selected from the group consisting of hydrogen, -[CH_2]$_q$-CH_3 and -$CH(CH_3)_2$; R_9 is -[CH_2]$_p$; p is a number from 3 to 6 and q is a number from 0 to 3. This polymer, as disclosed by MacDonald *et al.,* is an example of an acrylamide based polymer that is suitable for the ion exchange coating 30 and that is stable in the presence of chlorine and sodium hydroxide.

[0030] In another example, the ion exchange coating 30 can be a cross-linked polymer of the monomer compound below:

R= CH_3, CH_2CH_3 or $CH(CH_3)_2$; n= 1 or 2; and m = 1, 2 or 3.

[0031] This second polymer is an example of an acrylamide based polymer that is suitable for the ion exchange coating 30 and that is stable in the presence of chlorine.

[0032] The ion exchange coating 30 transports hydroxide ions out of the activated carbon substrate of the gas diffusion cathode 24 and into the feed space 26. Within the feed space 26, when a sodium chloride feed solution is used, the molar ratio of the chemical species relative to each other can drive the overall reaction of:

$$Cl_2 + 2NaOH \rightarrow NaClO + NaCl + H_20 \quad (5).$$

This overall reaction produces the oxidant biocide product of sodium hypochlorite (NaClO) and a sodium chloride solution.

[0033] Optionally, different feed solutions may be introduced into the feed space 26 to produce different oxidant-based biocides. For example, monovalent alkali halide solutions may be used to produce different alkali hypohalite products.

[0034] Optionally, the second anode side 23 is very close to the surface of the ion exchange coating 30 making the dimensions of the feed space 26 very tight. This tight feed space 26 is large enough to permit the flow of feed solutions into, and the reaction products out of, the electrochemical cell 20. This optional feature may improve the efficiency of the overall reaction (5) from above.

[0035] Optionally, the gas within the gas space 28 may be air and contain trace gases such as carbon dioxide, helium, hydrogen and the like. In this option, the presence of carbon dioxide within the gas space 28 may require a water softening treatment (not shown) of the feed solution prior to introduction into the feed space 26. The water softening reduces or removes water hardness ions such as calcium, magnesium, potassium, strontium, barium, and the like. The water softening treatment prevents the reaction of the carbon dioxide with the water hardness ions which can lead to the formation of undesirable carbonate ions and salts within the gas diffusion cathode 24. Carbonate ions and salts can decrease the rate of gas diffusion, which impairs the efficiency of the gas diffusion cathode 24. Further, carbonate ions can impair or compete with the transport of hydroxide ions by the ion exchange coating 30.

[0036] In an option of the anode 22, a metal oxide catalyst coating (not shown) is coated on at least the second anode side 23 that communicates with the feed space 26. The metal oxide catalyst coating can be ruthenium oxide, iridium oxide and the like. The metal oxide catalyst coating increases the efficiency of the oxidation of the chlorine ions to produce chlorine gas and electrons, see equation (1) above.

[0037] In an option of the gas diffusion cathode 24, the activated carbon substrate contains catalytic particles. Suitable catalytic particles are selected from platinum, ruthenium, iridium, rhodium and manganese dioxide and the like. The catalytic particles increase the efficiency of the hydroxide ion producing reaction (4) from above.

[0038] In a further option of the gas diffusion cathode 24, the current collector is made of nickel mesh or a mesh composed of a conductive titanium and nickel alloy.

[0039] Optionally, a coating of polytetrafluroethylene (PTFE) can be positioned on the second cathode side 27 of the gas diffusion cathode 24 to provide a hydrophobic barrier to the gas space 28.

[0040] In an optional feature of the electrochemical cell 20, at least two electrochemical cells 20 can be placed in series so that the feed solution flows from one electrochemical cell 20 to the next. This series arrangement can increase the production of oxidant-based biocides.

[0041] In operation, an electrolyte feed solution, for example sodium chloride, is introduced between the anode 22 and the gas diffusion cathode 24. The presence of dissociated sodium ions and chloride ions allows the electric circuit to be completed between the anode 22 and the gas diffusion cathode 24. The complete electric circuit provides a flow of electrons to drive the oxidation reaction to produce oxidation products at the anode 22. For example, see equation (1). The flow of electrons also drives the reduction reaction to produce reduction products at the gas diffusion cathode 24, for example, see equation (4). When the feed solution is sodium chloride, chlorine ions are oxidized into chlorine gas at the anode 22. Whereas, at the gas diffusion cathode 24, oxygen from the gas space 28 is reduced to form hydroxide ions. The ion exchange coating 30 of the gas diffusion cathode 24 transports the hydroxide ions out of the gas diffusion cathode 24 to react with the chlorine gas to produce sodium hypochlorite within the feed space 26.

[0042] Figure 3 depicts the use of the electrochemical cell 20 in a water treatment system 150 for the treatment of a target water circulation system. The water treatment system 150 comprises an input line 152, an output line 154 and a downstream process 156. The input line 152 conducts a feed solution towards the electrochemical cell 20, which is adapted to receive the feed solution within the feed space 26. The output line 154 conducts the electrochemical products (for example sodium hypochlorite and sodium chloride) away from the feed space 26 to the downstream process 156. The water treatment system 150 can be physically located close enough to the target water circulation system that the output line 154 can conduct the oxidant-based biocide products directly into the target water circulation system, shown as the downstream process 156 in Figure 3. Additionally, the downstream process 156 can include a

storage vessel (not shown) where the electrochemical products are stored for introduction into the target industrial water circulation system as needed, for example, if the electrochemical cell 20 production exceeds the demands of the target water circulation system.

[0043] Optionally, the water treatment system 150 is located at a different physical location than the target water circulation system. In this option, the downstream process 156 is a storage vessel to store the oxidant-based biocide products for transport to the target water circulation system.

[0044] In an additional optional feature of the water treatment system 150, a recirculation line 158 (shown as the dotted lines in Figure 3) is included to recirculate at least a portion of the electrochemical products back into the input line 152 or directly into the electrochemical cell 20. In this optional feature the recirculation line 158 can include a pumping system (not shown) and possibly a secondary storage vessel (not shown).

[0045] Table 3 below, provides a comparison of some of the calculated characteristics of a typical membrane based, electrolysis cell and the electrochemical cell 20.

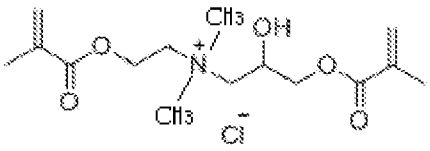
Table 3 - A comparison of the calculated characteristics of typical membrane based, electrolysis cell and the electrochemical cell 20.

	Typical Cell	Electrochemical cell 20
Anode	Coated titanium	Coated titanium
Cathode	Titanium	Gas diffusion cathode (24) with anion exchange coating (30)
Calculated Working potential (V)	Anode: $Cl_2 + 2e^- \rightarrow 2Cl^-$ E = 1.26V Cathode: $H_2O + 2e^- \rightarrow H_2 + 2OH^-$ E= -0.828 V Ecell = 2.188 V	Anode: $Cl_2 + 2e^- \rightarrow 2Cl^-$ E = 1.26V Cathode: $O_2 + 2H_2O + 4e^- \rightarrow 4OH^-$ E= 0.4V Ecell = 0.96 V
Calculated Energy Consumption (kWh/kg Cl_2)	1.55	0.62
H_2 Generation	Yes	Minimal to none
Feed solution salinity (NaCl g/l	≤ 30	10 to a saturated solution

H_20)		
Calculated Product Concentration of NaClO (g/l)	8	191
Calculated Water Consumption (l/kg Cl_2)	126	5.24

[0046] This comparison of the calculated characteristics from Table 3 is based upon the assumption of using pure oxygen within the gas space 28 and the anode and the cathode have no electrical resistance. From Table 3, the advantages of the electrochemical cell 20 at least include: a decreased working potential; decreased energy consumption per mass of product; minimal to no hydrogen gas production, which can pose safety hazards; a wide range of feed solution concentration, up to and including a saturated feed solution; increased product concentration; and decreased water consumption per mass of product.

[0047] An experiment was performed to determine the actual production and electrical properties of the electrochemical cell 20 under controlled conditions. In this experiment, both the anode 22 and the gas diffusion cathode 24 are 16cm x 8cm in size and the anode 22 is a commercially available titanium coated electrode. The catalytic particles within the activated carbon substrate are manganese dioxide. The ion exchange coating 30 is a product of copolymerizing and cross-linking reaction of the monomer structure provided below:



[0048] Figures 4, 5, 6 and 7 depict the outcomes measured during this experiment. During the experiment, four different concentrations of sodium chloride feed solution were used: 50g/l, 100g/l, 200g/l and 300g/l.

[0049] For the 50g/l feed solution experiment, current densities of 120, 172 and 258 mA/cm^2 were applied. For the 100g/l feed solution experiment, current densities of 86, 120 and 172 mA/cm^2 were applied. For the 200g/l feed solution experiment, current

densities of 120, 172 and 215 mA/cm^2 were applied. For the 300g/l feed solution experiment, current densities of 172, 215 and 258 mA/cm^2 were applied.

[0050] The feed solution was introduced into the feed space 26 at various flow rates, as shown by the X-axis values of Figures 3, 4, 5 and 6. Additionally, the flow rate of air through the gas space 28 was approximately 2 to 6 times higher than the stoichiometric requirements of the four-electron reduction of oxygen, see reaction (4) from above.

[0051] Figure 4 demonstrates that the electrochemical cell 20 produces sodium hypochlorite product at various feed solution concentrations and various current densities. The highest feed solution concentration of 300g/l, as shown in Figure 4D, has the highest production of all the feed solution concentrations tested. Within Figure 4D, the highest current density of 258 mA/cm^2 causes the highest production of all parameters tested.

[0052] Figure 5 demonstrates that a current efficiency of substantially greater than 80% can be achieved with the electrochemical cell 20. The current efficiency is calculated by comparing the stoichiometry of the overall reaction; see reaction (5) from above, wherein the transfer of 2 mols of electrons generates 1 mol chlorine gas and 2 mol hydroxide ions, which ultimately generated 1 mol of NaClO. This one mol of sodium hypochlorite is compared to the amount of sodium hypochlorite actually produced to determine current efficiency.

[0053] Figure 6 demonstrates that the electrochemical cell 20 can operate with an energy consumption of approximately 3 kWhr/kg of sodium hypochlorite produced.

[0054] Figure 7 demonstrates that placing two electrochemical cells 20 in series increases the overall production of sodium hypochlorite.

[0055] Table 4 presents the comparative data of current efficiency and resistance between a blank calendered electrode; a calendered electrode with a selectively permeable ion exchange membrane; a screen printed electrode with a selectively permeable ion exchange membrane; and a calendered coated electrode, coated with the ion exchange coating 30, as described above. In these experiments, a sodium chloride feed solution at a concentration of 800ppm and at a flow rate of 10cm/s was utilized.

[0056] Table 4 - A comparison of current efficiency and resistance of various electrode arrangements.

	Current Efficiency (%)	Resistance (Ohms)
Blank calendered electrode	~30	0.253 ± 0.02
Calendered electrode with a selectively permeable ion exchange membrane	~85-90	0.39 ± 0.02
Screen printed electrode with a selectively permeable ion exchange membrane	~85-90	0.283 ± 0.02
Calendered and coated electrode, coated with the anion exchange coating	~85-90	0.17 ± 0.01

[0057] The calendered and coated electrode demonstrated an approximate 56% reduction in resistance, at the same current efficiency, in comparison to the calendered electrode with the selectively permeable ion exchange membrane. The calendered and coated electrode demonstrated an approximate 40% reduction in resistance, at the same current efficiency, in comparison to the screen printed electrodes with a selectively permeable ion exchange membrane.

[0058] Figure 8 demonstrates the comparison in energy consumption between a titanium coated carbon electrode that is used with a selectively permeable ion exchange membrane and a coated electrode that is coated with the ion exchange coating 30, as described above. At the onset of the current, the voltage is 53% lower in the anion exchange coated electrode.

[0059] This written description uses examples to disclose the invention, including the best mode, to enable any person skilled in the art to practice the invention, including making and using any devices or systems and performing any incorporated methods. The patentable scope of the invention is defined by the claims, and may include other examples that occur to those skilled in the art.

1. An electrochemical cell for producing oxidant-based compounds, comprising:

   a. a source of electrical power;

   b. a gas diffusion cathode with an ion exchange coating;

   c. an anode opposing the ion exchange coating;

   d. a plenum adapted to receive gas and in fluid communication with the gas diffusion cathode; and

   e. The electrochemical cell adapted to receive a fluid between the anode and the ion exchange coating, the fluid completing an electrical circuit between the anode and the gas diffusion cathode.

2. The electrochemical cell of claim 1, wherein the ion exchange coating is an anion exchange coating.

3. The electrochemical cell of claim 2, wherein the anion exchange coating is oxidant stable.

4. The electrochemical cell of claim 2, wherein the anion exchange coating is oxidant stable and caustic stable.

5. The electrochemical cell of claim 1, wherein the ion exchange coating is positioned on a first side of the gas diffusion cathode; the plenum is in communication with a second side of the gas diffusion cathode; and, the first side is opposite to the second side.

6. The electrochemical cell of claim 5, the gas diffusion cathode further comprising an electron collector and an activated carbon substrate, the electron collector and the activated carbon substrate positioned between the first side and the second side.

7. The electrochemical cell of claim 4, the activated carbon substrate further comprising catalytic particles selected from the group consisting of platinum, ruthenium, iridium, rhodium and manganese dioxide.

8. The electrochemical cell of claim 1, further comprising a polytetrafluroethylene layer between the plenum and the gas diffusion cathode.

9. The electrochemical cell of claim 1, the anode further comprising a catalyst layer, the catalyst layer facing the ion exchange coating and including ruthenium oxide or iridium oxide.

10. The electrochemical cell of claim 1, wherein the anode is in tight proximity to the ion exchange coating.

11. The electrochemical cell of claim 1, wherein the gas includes at least some oxygen, the fluid is a solution of sodium chloride and the oxidant-based compound produced is sodium hypochlorite.

12. A method for producing an oxidant-based compound, comprising:

a. provide an electric current through a feed solution that includes a plurality of dissociated anions and a plurality of dissociated cations;

b. oxidize at least a portion of the plurality of dissociated anions to produce oxidation products;

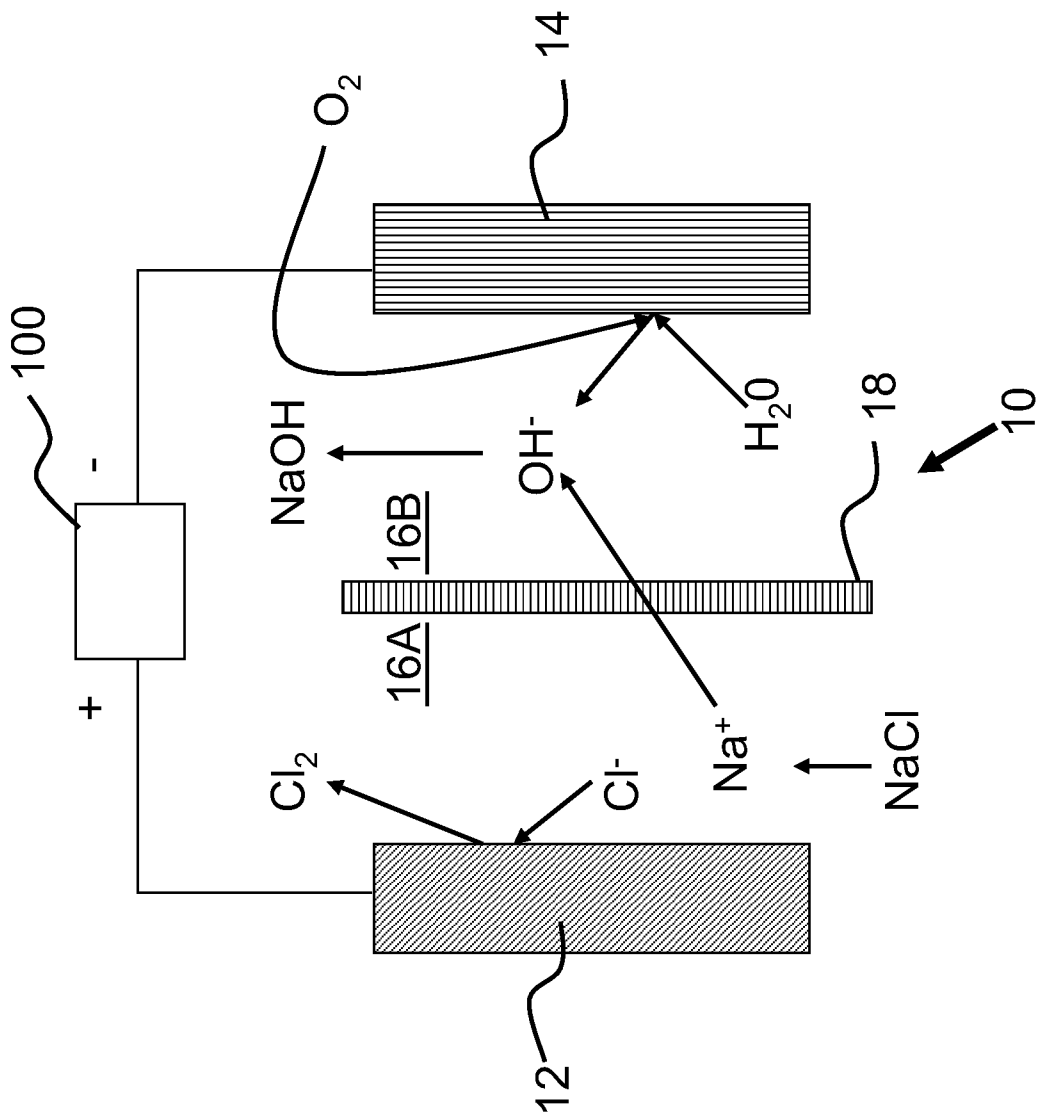
c. reduce at least some oxygen gas to produce a plurality of hydroxide ions;

d. transport the plurality of hydroxide ions into proximity with the oxidation products; and

e. provide a molar ratio that drives the plurality of hydroxide ions to react with the oxidation products and the plurality of dissociated cations to produce an oxidant-based compound.

13. The method of claim 12, wherein the feed solution is an alkali halide solution, the oxidation products are diatomic halide gas and the oxidant-based compound is an alkali metal hypohalite.

14. The method of claim 13, where the alkali halide solution is sodium chloride.



Prior art
Fig.1

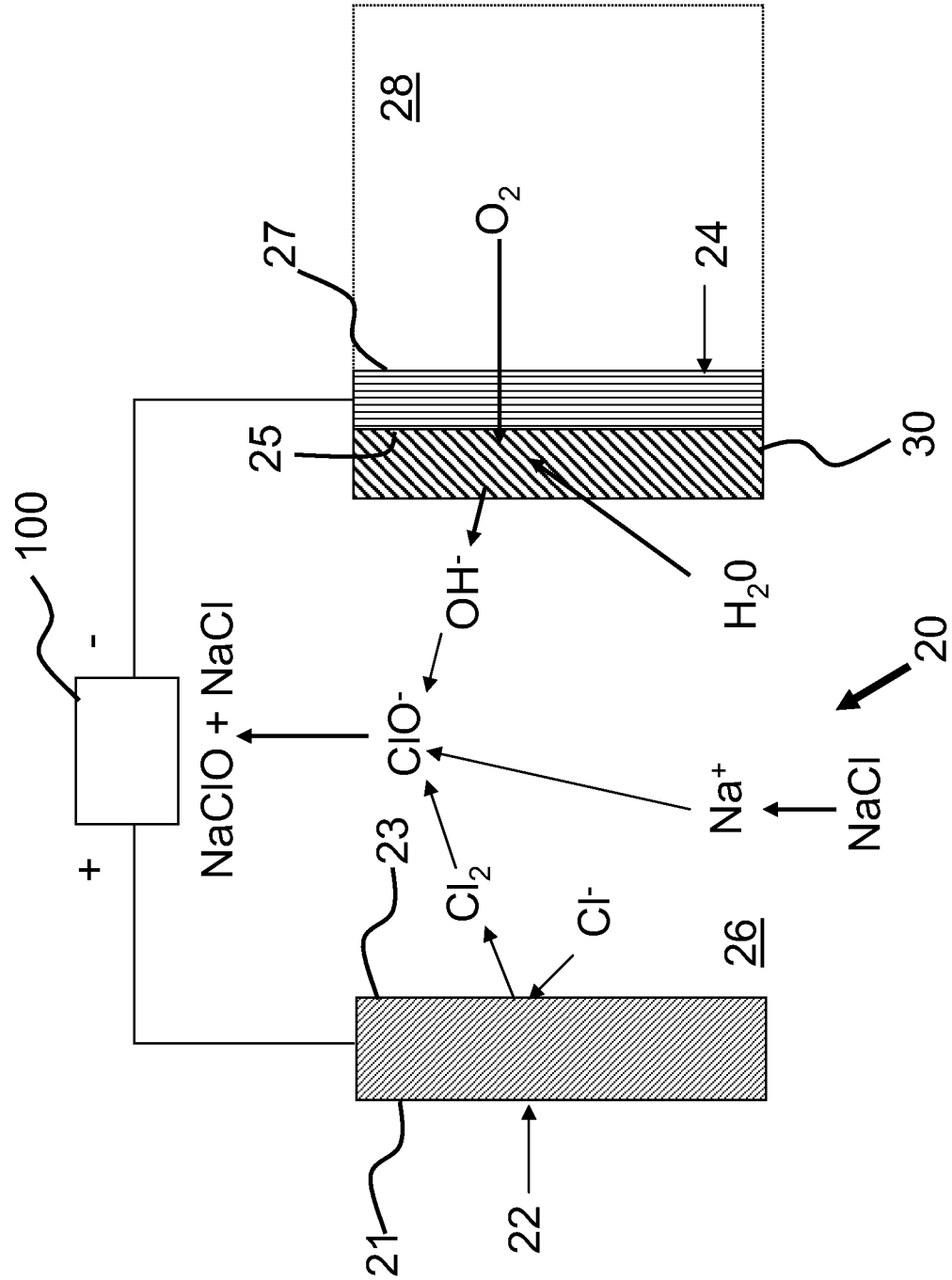

28
O_2
27
24
25
30
100
-
OH^-
H_2O
$NaClO + NaCl$
ClO^-
20
Na^+
NaCl
23
Cl_2
Cl^-
26
+
21
22

Fig.2

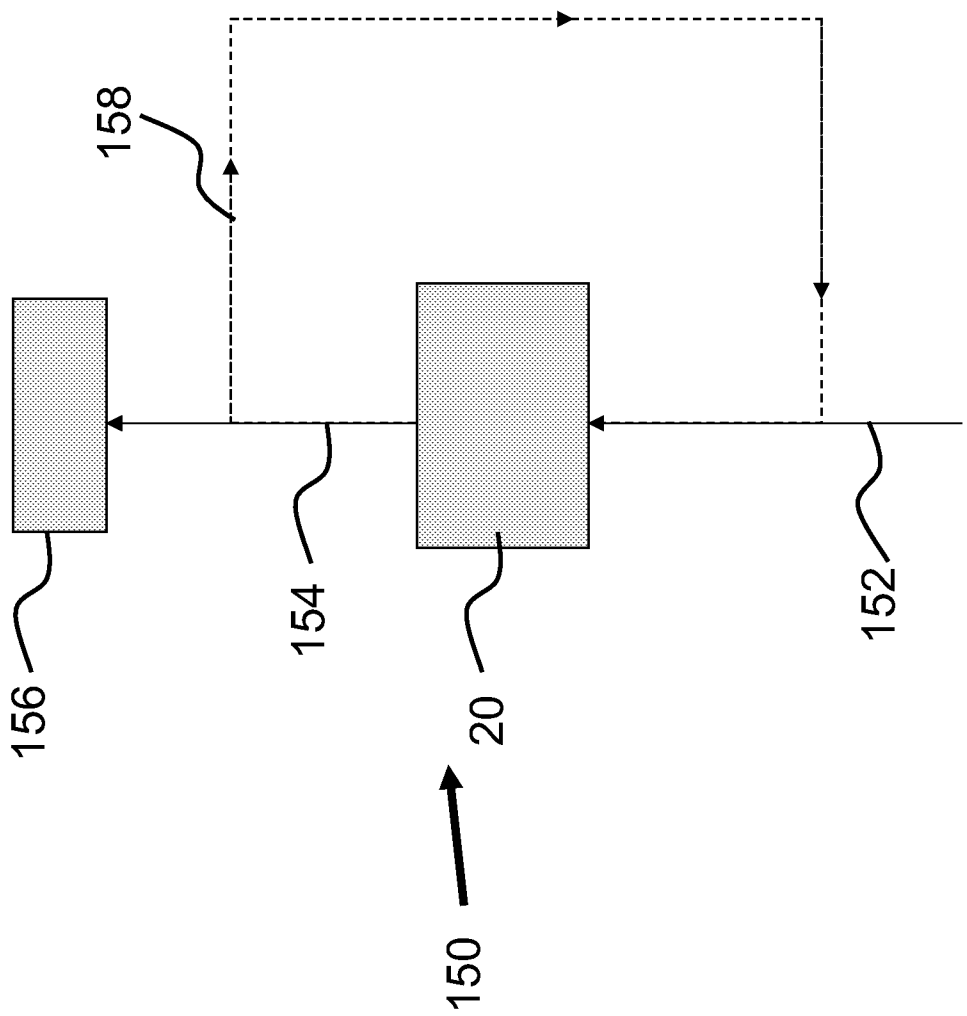


Fig.3

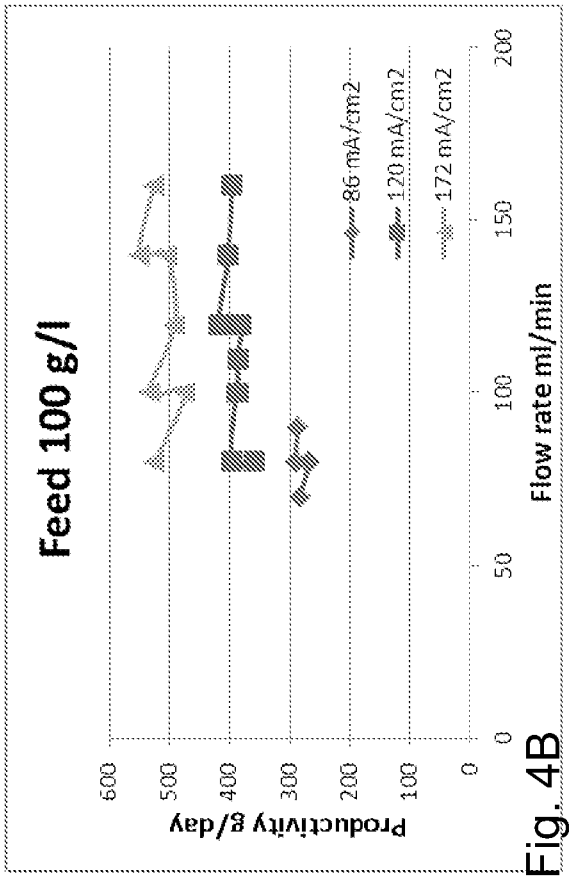


Fig. 4B

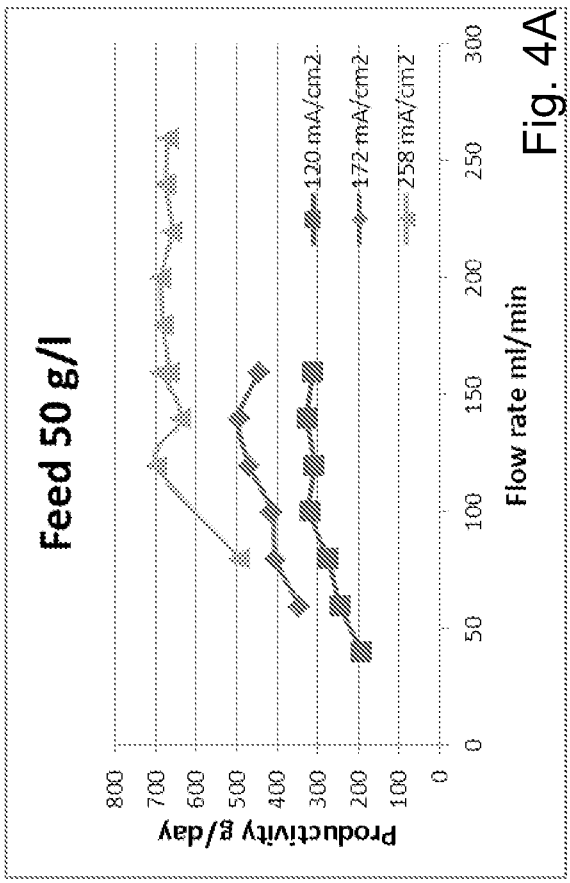


Fig. 4A

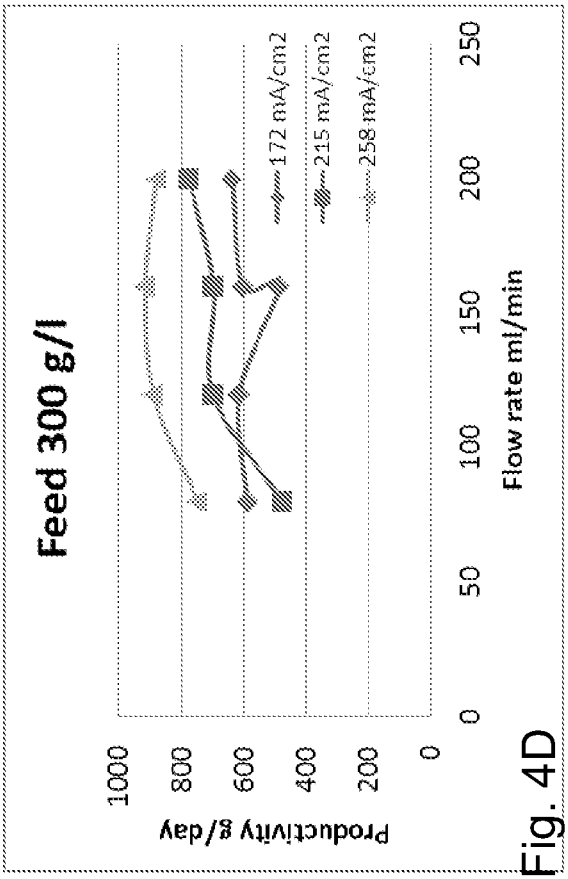


Fig. 4D

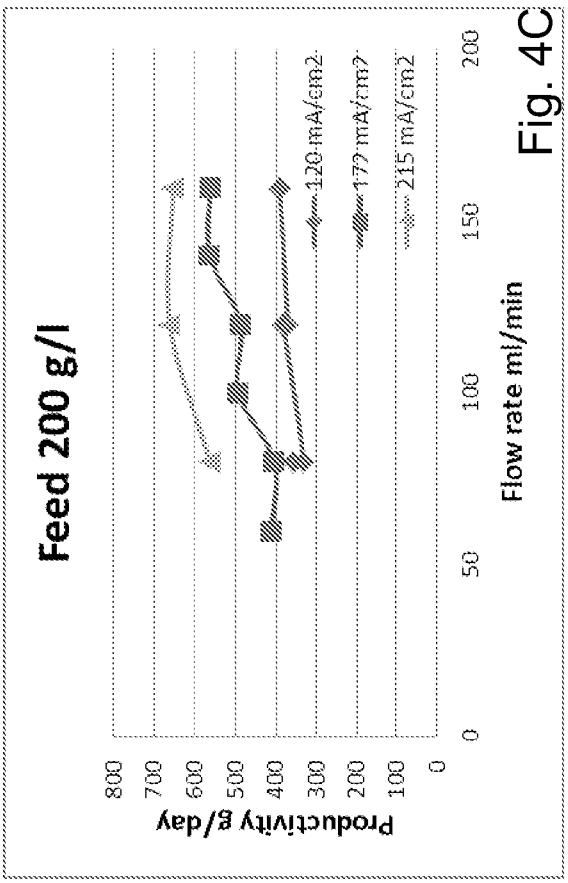


Fig. 4C

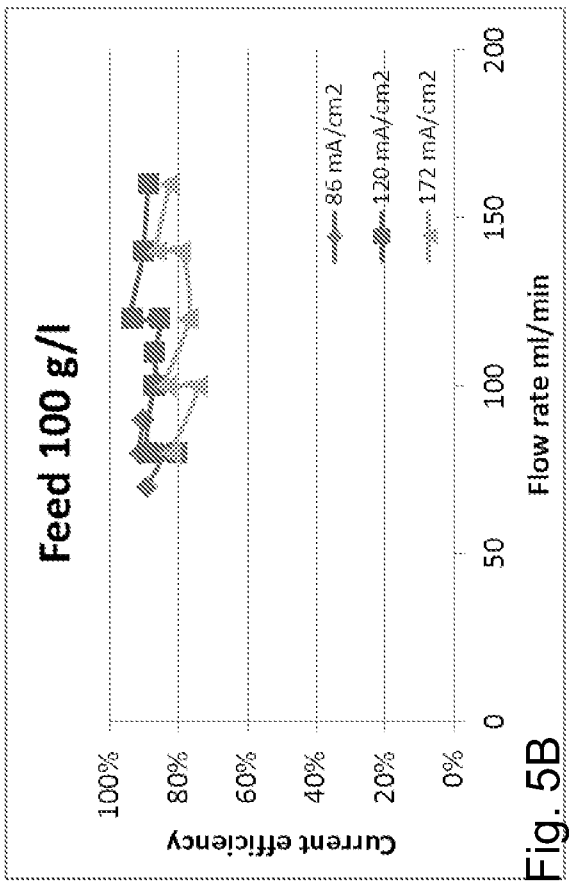


Fig. 5A

Fig. 5B

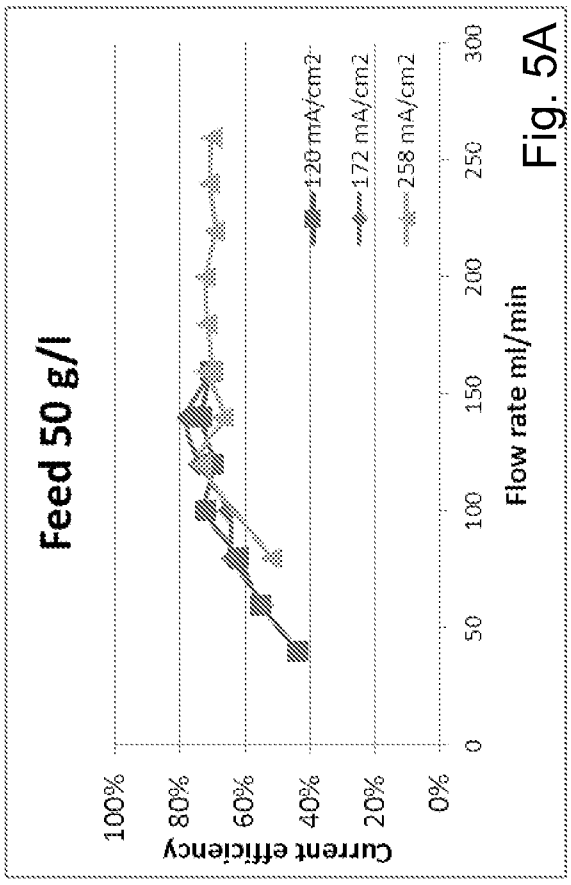


Fig. 5C

Fig. 5D

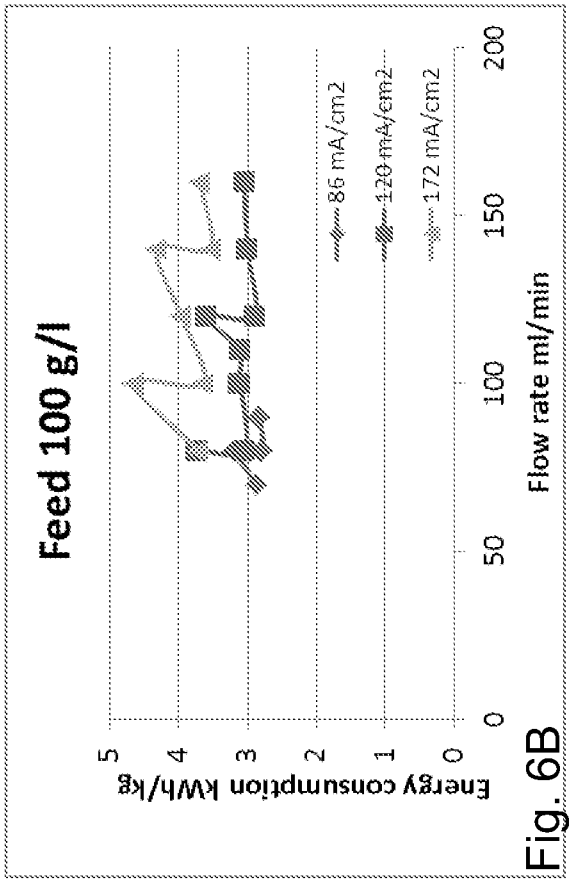


Fig. 6B

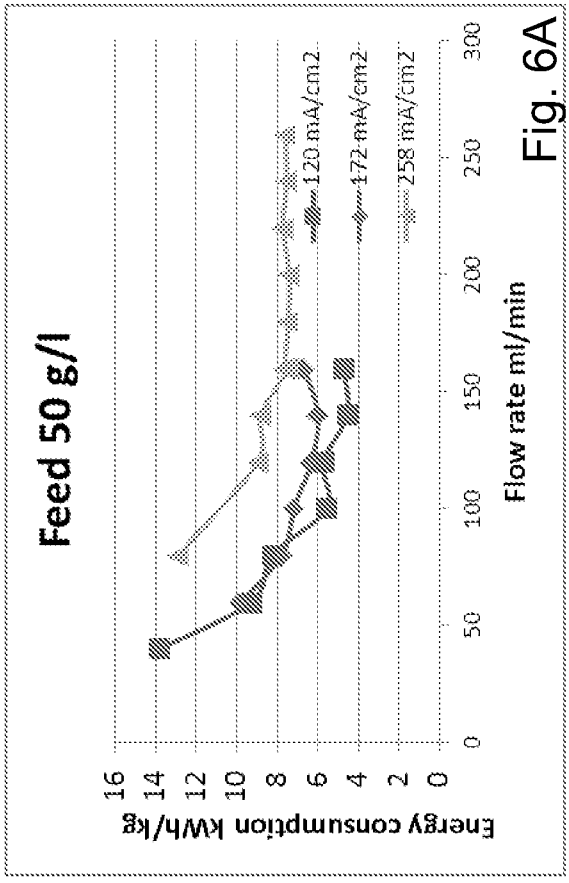


Fig. 6A

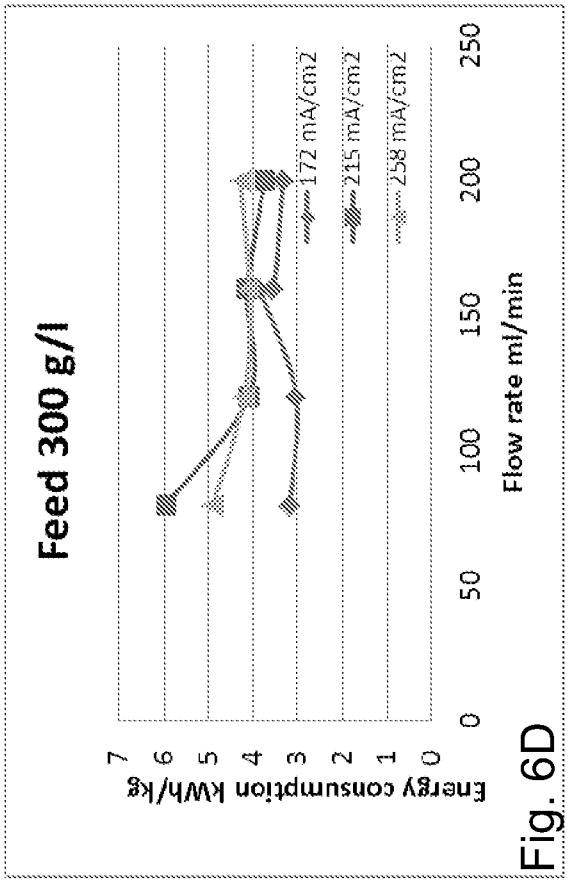


Fig. 6D

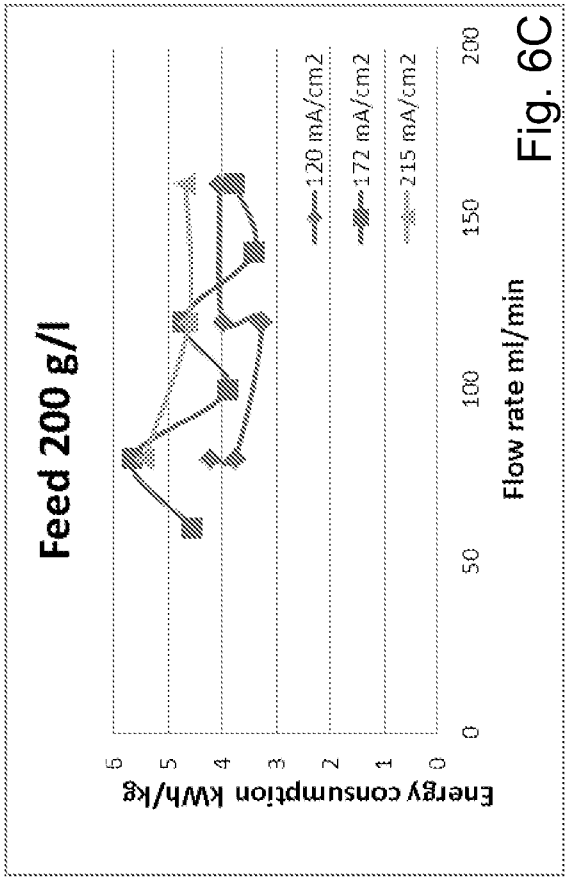


Fig. 6C

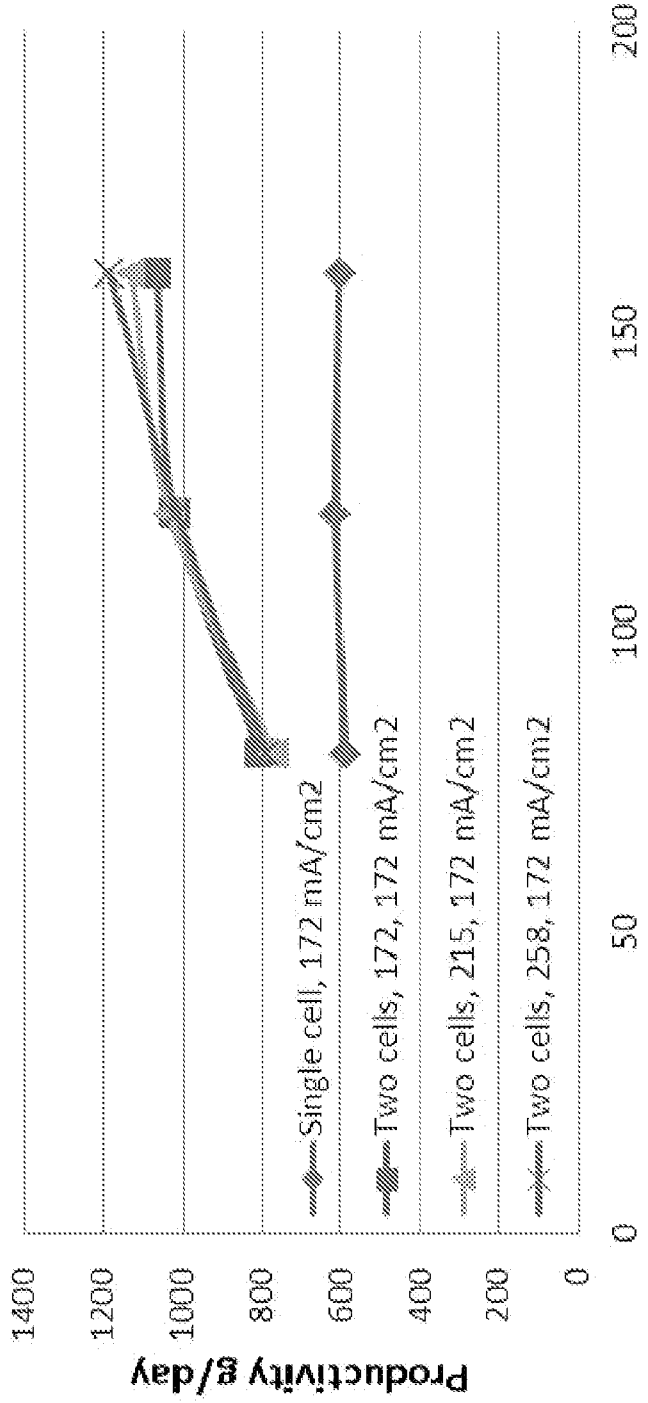
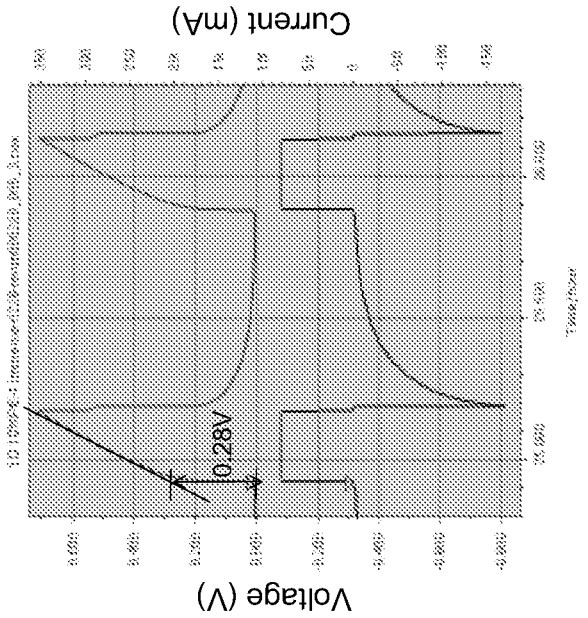
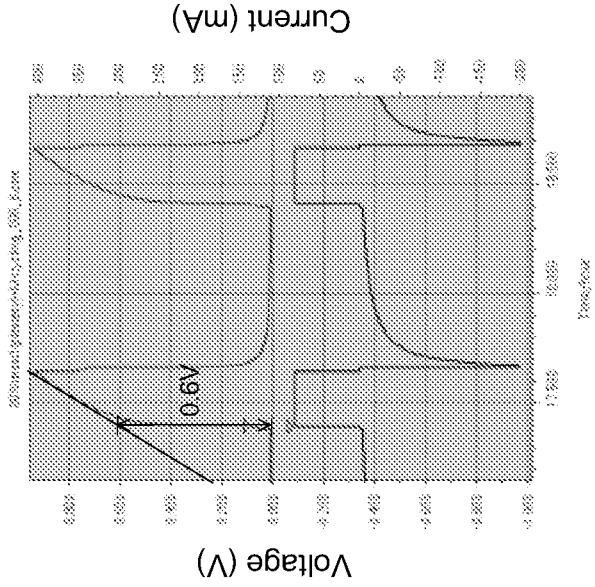

Productivity g/day
1400
1200
1000
800
600
400
200
0
0
50
100
150
200
Flow rate ml/min
Single cell, 172 mA/cm2
Two cells, 172, 172 mA/cm2
Two cells, 215, 172 mA/cm2
Two cells, 258, 172 mA/cm2

Fig. 7



Anion exchange coated electrode



Control electrode

Fig. 8

INTERNATIONAL SEARCH REPORT

International application No.
PCT/CN2011/083772

A. CLASSIFICATION OF SUBJECT MATTER

See Extra Sheet

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: C25B/-

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

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

WPI;EPODOC;CNKI;ISI;CNPAT: sodium,hypochlorite,NaC10,cathode,anode,electrode,0_2,oxygen

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN201901710U (CHINA INSTITUTE OF WATER RESOURCES AND HYDROPOWER RESEARCH) 20 Jul. 2011(20.07.2011) whole documents	1-14
A	JP62-23992A (JAPAN CARLIT CO. LTD.) 31 Jan. 1987(31.01.1987) whole documents	1-14
A	RU2110999C1 (MEDEK CO. LTD.) 20 May 1998(20.05.1998) whole documents	1-14

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim (S) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search
03 Jul. 2012(03.07.2012)

Date of mailing of the international search report
13 Sep. 2012 (13.09.2012)

Name and mailing address of the ISA/CN
The State Intellectual Property Office, the P.R.China
6 Xitucheng Rd., Jimen Bridge, Haidian District, Beijing, China
100088
Facsimile No. 86-10-62019451

Authorized officer
Xu, Guoxiang

Telephone No. (86-10)62412631

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/CN201 1/083772

Patent Documents referred in the Report	Publication Date	Patent Family	Publication Date
CN201901710U	20.07.2011	None	
JP62-23992A	31.01.1987	None	
RU2110999C1	20.05.1998	None	

INTERNATIONAL SEARCH REPORT

International application No.

PCT/CN2011/083772

Continuation of A. CLASSIFICATION OF SUBJECT MATTER

C25B1/34 (2006.01) i
C25B1/46 (2006.01) i