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(54) ELECTROLYSIS PROCESS AND APPARATUS

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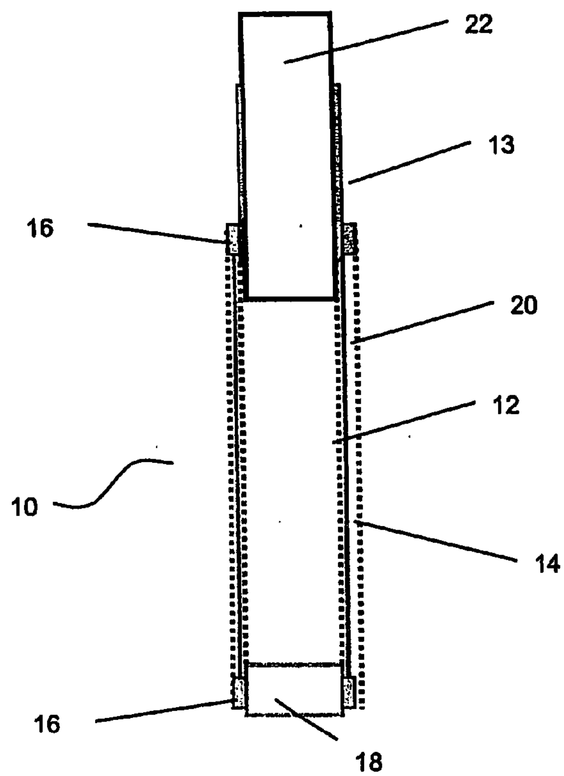
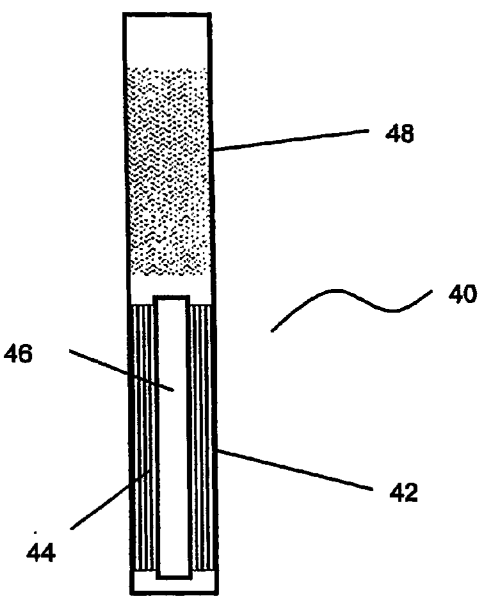
(57) ABSTRACT

The invention provides an electrolysis apparatus for the production of hydrogen and oxygen, which apparatus includes at least two or more tubular electrodes, at least one of which is an inner electrode located in at least one outer electrode, and a separator interposed between the inner and outer electrodes and substantially coextensive therewith. One or more of the electrodes may, in use, be an anode. One or more of the electrodes may, in use, be a cathode.





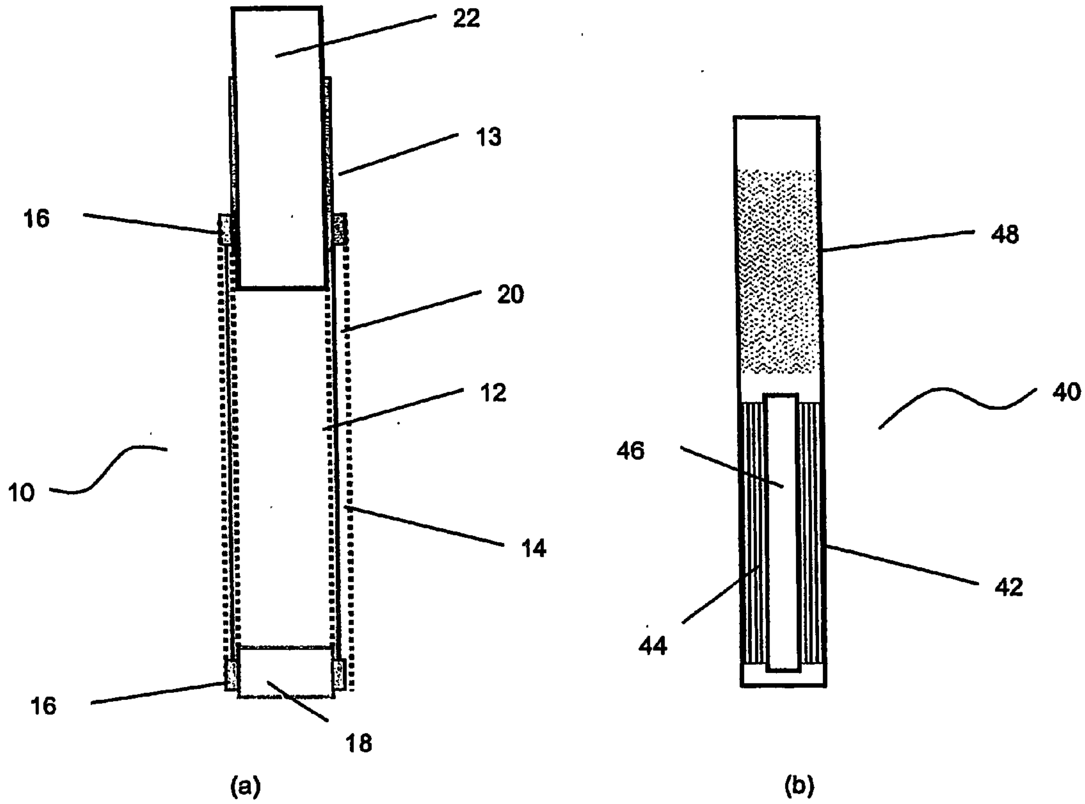


FIGURE 1

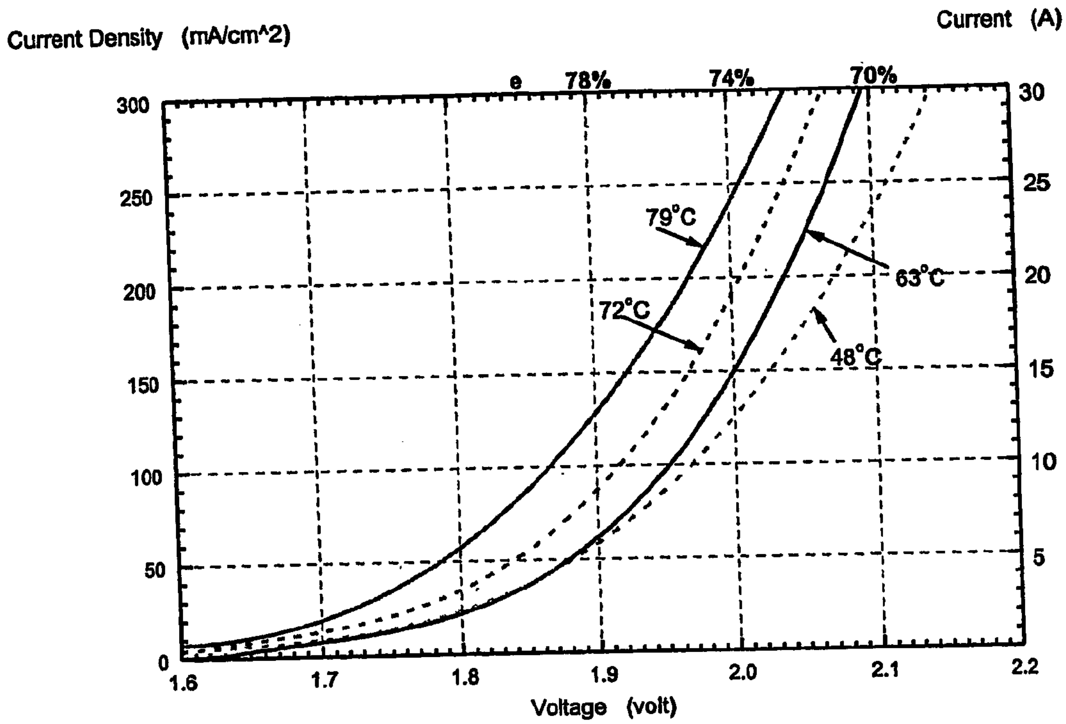

Current Density (mA/cm^2)
Current (A)
e 78% 74% 70%
300
250
200
150
100
50
0
30
25
20
15
10
5
79°C
72°C
63°C
48°C
1.6
1.7
1.8
1.9
2.0
2.1
2.2
Voltage (volt)

FIGURE 2

ELECTROLYSIS PROCESS AND APPARATUS

FIELD OF THE INVENTION

[0001] The invention relates to electrolysis of a fluid. In particular the invention relates to an electrolysis process and an apparatus for carrying out the process.

BACKGROUND OF THE INVENTION

[0002] Due to concerns about the environment, pollution and depletion of limited fossil energy sources attention is given worldwide to renewable clean energy sources.

[0003] Due to the intermittent nature of these sources (solar, wind, etc.) some means of energy storage is required.

[0004] Hydrogen gas produced by electrolysis during the availability of the primary energy has been identified as a viable way to store energy. It can also serve as an energy carrier where hydrogen is produced at the site of the source (nuclear, fossil or renewables) and converted to hydrogen through electrolysis which is then transported to where the energy is required. Hydrogen is further a candidate for fuel for vehicles utilizing high efficient fuel cells.

[0005] The basic science involved in electrolysis is well known. Commercial plants have been in operation for decades, but due to the projected large future demand for hydrogen the following problems were identified with present technologies as set out in a United Nations report—Renewable Energy—United Nations Project, Johansen et al, p 929:

> [0006] "Changing the cell configuration and geometry with the goal of reducing the cell resistance by a factor of 3 to 10 thereby reducing the ohmic voltage losses
>
> [0007] Developing new and inexpensive electrocatalyst materials able to reduce the sum of anodic and cathodic overvoltage to about 0.3 volt or less
>
> [0008] Developing new diaphragm materials that are superior to conventional asbestos cloth."

[0009] The applicant has identified a need for an improved electrolysis cell, and a method of producing gasses by electrolysis, with high current density and efficiency, cheap and simple construction and with high gas purities without the need for subsequent purification.

SUMMARY OF THE INVENTION

[0010] According to a first aspect of the invention, there is provided an electrolysis apparatus for the production of hydrogen and oxygen, which apparatus includes at least:

> [0011] two or more tubular electrodes, at least one of which is an inner electrode located in at least one outer electrode; and
>
> [0012] a separator interposed between the inner and outer electrodes and substantially coextensive therewith.

[0013] One or more of the electrodes may, in use, be an anode.

[0014] One or more of the electrodes may, in use, be a cathode.

[0015] The separator may be positioned between the anode and the cathode so that there is substantially no gap between the separator and the anode, and the separator and the cathode.

[0016] A portion of the separator may be bonded to a support structure associated with the anode and/or the cathode using, for example, an epoxy sealant.

[0017] The electrodes may be made of an apertured conductive material.

[0018] The electrodes may be plated.

[0019] The apertured conductive material may be a sintered body having flow channels extending between the inside and the outside thereof.

[0020] The apertured conductive material may be a single layer mesh.

[0021] The apertured conductive material may be made of two or more layers of mesh.

[0022] The apertured conductive material may be a three dimensional mesh.

[0023] The apertured conductive material may comprise a conductive polymer. The polymer may be coated with a conductive material, for example, a metal.

[0024] The apertured conductive material may comprise of silver, nickel, stainless steel or copper.

[0025] The anode and cathode may be substantially concentric.

[0026] A plurality of anodes and cathodes of various diameters may be nested to provide a high electrolysis surface area to electrolysis apparatus volume ratio.

[0027] The cathode and/or anode may be made of one or more first material i.e. the substrate, and plated with a second material or composition of matter which is electrically conductive.

[0028] The anode may be made of a conductive metal, for example, stainless steel mesh.

[0029] The anode may comprise two or more layers of stainless steel mesh.

[0030] The anode may be nickel plated.

[0031] The cathode may be made of a conductive metal, for example, stainless steel mesh.

[0032] The cathode may comprise two or more layers of stainless steel mesh.

[0033] The cathode may be nickel plated.

[0034] The mesh may be nickel plated before or after the layers of stainless steel are placed together.

[0035] One or more of the tubular anode and the cathode may be closed off at one end such that, in use, an overpressure is established within the closed off tubular anode or cathode.

[0036] One or more conductors may be provided in association with the anode and/or the cathode.

[0037] In one embodiment a tubular mesh conductor is provided on the outside of the anode and another on the inside of the cathode.

[0038] In another embodiment, the conductors are in the form of one or more conductive strips attached to a portion or portions of the anode and/or the cathode.

[0039] The separator may comprise one or more layers of a fibrous material.

[0040] The separator may comprise one or more layers of a wettable material.

[0041] The separator may comprise one or more layers of a wettable fibrous material.

[0042] The separator may comprise one or more layers of cellulose containing composition.

[0043] The cellulose containing composition may be paper.

[0044] The paper may be a filter paper.

[0045] The filter paper may be chemical resistant filter paper.

[0046] The filter paper may be medium to fast grade filter paper.

[0047] In an embodiment, the apparatus may consist of:

[0048] a tubular apertured stainless steel mesh anode electrode; and

[0049] a tubular apertured nickel-plated stainless steel cathode electrode, wherein the cathode and anode are substantially concentric and the cathode lies within the anode; and

[0050] a separator means between the anode and cathode comprising one or more layers of a fibrous material.

[0051] The apparatus may, in use, include an alkaline electrolyte solution.

[0052] The apparatus may, in use, include an acidic electrolyte solution.

[0053] The apparatus may include means for supplying and conducting electrical current to the electrodes.

[0054] The apparatus may include means for drawing off the gasses.

[0055] The apparatus may include means for removing vapour from the generated gasses.

[0056] A plurality of anode and cathode sets may be used in parallel.

[0057] A plurality of anode and cathode sets may be used in series.

[0058] The anode and cathode sets and the conductors may be configured in such a way that a plurality of such sets is arranged around a tubular conductor for the anodes, all in a common electrolyte. Each cathode may be connected to its own conductor.

[0059] The invention extends to a separator for an electrolysis apparatus, which separator is interposed between the anode and the cathode of the apparatus, said separator comprising one or more layers of fibrous material.

[0060] The fibrous material may be wettable.

[0061] The wettable material may be a cellulose containing composition.

[0062] The cellulose containing composition may be paper.

[0063] The paper may be a filter paper.

[0064] The filter paper may be chemical resistant filter paper.

[0065] The filter paper may be medium to fast grade filter paper.

[0066] The invention extends to an electrolysis process carried out in an apparatus substantially as described above.

[0067] The process may include:

[0068] establishing a potential difference between the anode and the cathode; and

[0069] contacting the anode and cathode with an electrolyte from which gasses are liberated by electrolysis.

[0070] The process may include contacting the apparatus with an electrolyte solution of between 10% and 50% by mass of electrolytic salts, typically from 20% to 35% by mass.

[0071] The electrolyte solution may be a KOH, NaOH, or other alkaline solution.

[0072] The electrolyte solution may be acidic.

[0073] The process may be carried out at from 40° C. to 100° C., typically from 60° C. to 90° C.

[0074] The electrodes may be submerged in the electrolyte.

[0075] The electrolyte may be pumped through the separator of the apparatus.

[0076] The electrolyte may be drip fed through the separator, thereby maintaining the separator saturated with electrolyte while minimizing the volume of fluid being circulated.

DESCRIPTION OF AN EXAMPLE OF THE INVENTION

[0077] The invention will now be described, by way of a non-limiting example only, with reference to the accompanying diagrammatic drawings and graph.

EXAMPLE

[0078] A cross section of an electrode pair **10** is shown in **FIG. 1**(*a*).

[0079] The electrodes **12**, **14** of the electrode pair **10** are made of a stainless steel mesh.

[0080] The nickel plated copper pipe **22** is used as support and electrical connector to the cathode. It serves also to extract the hydrogen gas.

[0081] The top part of the pipe is covered with insulating material **13** to prevent contact with the electrolyte.

[0082] A cylindrical plastic plug **18** serve as support and seal of the inner cathode.

[0083] The cathode, anode and separator are sealed **16** at the bottom and top ends to prevent any mixing of the gasses.

[0084] Electrical connection to the outer anode is achieved by connecting it with nickel plated copper strips to a nickel plated copper conductor immersed in the electrolyte.

[0085] The inner electrode **12** i.e. the H_2 cathode consists of two layers of fine mesh stainless steel. A copper pipe **22** forms the electrical contact. The total length is 130 mm with 100 mm exposed to the electrolyte. The inner electrode **12** is nickel plated to a thickness of about 200 μm on the mesh. Two layers of medium filter paper **20** are wrapped around this mesh and the end points sealed with epoxy **16**

[0086] The outer electrode **14**, i.e. the O_2 anode consists of two layers of fine mesh stainless steel. The anode **14** is not plated with nickel. The bottom of the electrode **14** is sealed with a plastic stopper **18**. An electrical contact is attached to the anode (not shown).

[0087] The electrode pair is immersed in the electrolyte. The electrolyte enters the inner pipe by liquid diffusion through the porous separator. The generated gasses are prevented from passing through the separator.

[0088] A plastic pipe **22** provides support.

[0089] The structure of a demister **40** is shown in **FIG. 1**(*b*).

[0090] The demister **40** consists of a 30 cm 22 mm diameter nickel plated copper pipe. The lower half **42** of the pipe contains rolled layers of course mesh stainless steel **44** around a plastic bar **46** with 10 mm diameter. The roll fits snugly in the pipe and traps all KOH spray and condenses most of the water vapour. The top half **48** is filled with brass curling to trap the remaining water vapour and cool the gasses down to room temperature. The heat is liberated to the atmosphere by normal convection and radiative cooling.

[0091] The above electrodes were tested using apparatus as described below.

[0092] A reactor which consists of a transparent plastic jar of 10 cm diameter and height 40 cm was used.

[0093] A KOH solution (25% m/m) was placed in the jar. The electrolyte was kept at a constant temperature for each experiment by supplying external heating. The electrode pair (as described above) was submerged in the electrolyte.

[0094] The generated gasses pass through demisters **40** on top of the reactor. These demisters **40** trap the KOH spray and water vapour at the high temperatures and deliver cooled dry gasses at room temperature.

[0095] A series of experiments were performed, measurement taken and current density (J-V) curves drawn as shown in **FIG. 2**.

[0096] The purity of the gasses produced with a 79° C. electrolyte was above 99.9%, without the need for further (separate) purification.

1-61. (canceled)

62. An electrolysis apparatus including:

an elongate generally tubular shaped outer electrode;

an elongate generally tubular shaped inner electrode, the inner electrode being positioned to extend generally longitudinally within the outer electrode; and

a separator extending between the inner and the outer electrodes, in which at least one of the inner and the outer electrodes includes two generally tubular shaped formations positioned one within the other, immediately adjacent each other, and each of which are of a foraminous electrically conductive construction.

63. The electrolysis apparatus as claimed in claim 62, in which the two generally tubular shaped formations of the at least one of the inner and outer electrodes are formed from an electrically conductive mesh.

64. The electrolysis apparatus as claimed in claim 62, in which the two generally tubular shaped formations of the at least one of the inner and outer electrodes are formed from a material including stainless steel.

65. The electrolysis apparatus as claimed in claim 62, in which the two generally tubular shaped formations of the at least one of the inner and outer electrodes are formed from a material including a conductive polymer.

66. The electrolysis apparatus as claimed in claim 62, in which the two generally tubular shaped formations of the at least one of the inner and outer electrodes are coated with an electrically conductive material.

67. The electrolysis apparatus as claimed in claim 66, in which the two generally tubular shaped formations have been placed together and then coated with an electrically conductive material while in a placed together condition.

68. The electrolysis apparatus as claimed in claim 66, in which the two generally tubular shaped formations are coated with an electrical conductive material including nickel.

69. The electrolysis apparatus as claimed in claim 62, in which the two generally tubular shaped formations of the at least one of the inner and outer electrodes define a cathode of the electrolysis apparatus.

70. The electrolysis apparatus as claimed in claim 62, in which each of the inner and the outer electrodes include two generally tubular shaped formations positioned one within the other, immediately adjacent each other, and each of the generally tubular shaped formations are of a foraminous electrically conductive construction.

71. The electrolysis apparatus as claimed in claim 70, in which each of the two generally tubular shaped formations of each of the inner and outer electrodes are formed from an electrically conductive mesh.

72. The electrolysis apparatus as claimed in claim 70, in which each of the two generally tubular shaped formations of each of the inner and outer electrodes are formed from a material including stainless steel.

73. The electrolysis apparatus as claimed in claim 70, in which each of the two generally tubular shaped formations of each of the inner and outer electrodes are formed from a material including a conductive polymer.

74. The electrolysis apparatus as claimed in claim 62, in which one of the inner and the outer electrodes includes nickel and the other one of the inner and the outer electrodes includes stainless steel.

75. The electrolysis apparatus as claimed in claim 74, in which the one of the inner and the outer electrodes which includes nickel defines a cathode of the electrolysis apparatus.

76. The electrolysis apparatus as claimed in claim 62, in which the separator includes a fibrous material.

77. The electrolysis apparatus as claimed in claim 76, in which the fibrous material includes cellulose.

78. The electrolysis apparatus as claimed in claim 76, in which the separator is of a wettable fibrous material.

79. An electrolysis apparatus including:

an elongate generally tubular shaped outer electrode;

an elongate generally tubular shaped inner electrode, the inner electrode being positioned to extend generally longitudinally within the outer electrode; and

a separator extending between the inner and the outer electrodes, at least one of the inner and the outer electrodes including a plurality of generally tubular shaped formations of a foraminous electrically conductive construction which are positioned one within the other, immediately adjacent each other, the generally tubular shaped formations having been coated with an electrically conductive material while in a placed together condition.

80. The electrolysis apparatus as claimed in claim 79, in which the plurality of generally tubular shaped formations of a foraminous electrically conductive construction are formed from a material including a conductive polymer.

81. The electrolysis apparatus as claimed in claim 79, in which the generally tubular shaped formations have been coated with an electrically conductive material including nickel while in a placed together condition.

82. An electrolysis apparatus which includes:

a separator; and

at least two electrodes, positioned on opposed sides of the separator, in which at least one of the electrodes is formed of a material including a conductive polymer.

83. The electrolysis apparatus as claimed in claim 82, in which the at least one of the electrodes which is formed of a material including a conductive polymer is coated with a conductive material.

84. The electrolysis apparatus as claimed in claim 83, in which the conductive material includes nickel.

85. An electrolysis apparatus as claimed claim 82, in which one of the at least two electrodes is in the form of an elongate generally tubular shaped outer electrode and the other of the at least two electrodes is in the form of an elongate generally tubular shaped inner electrode, the inner electrode being positioned to extend generally longitudinally within the outer electrode, the separator extending between the inner and the outer electrode.

86. An electrolysis apparatus as claimed in claim 85, in which at least one of the inner and the outer electrodes is foraminous.

87. An electrolysis apparatus as claimed in claim 85, in which the electrodes define a closed off end.

88. A method of performing electrolysis including:

providing an electrolysis apparatus having an elongate generally tubular shaped outer electrode, an elongate generally tubular shaped inner electrode, the inner electrode being positioned to extend generally longitudinally within the outer electrode and a separator extending between the inner and the outer electrodes;

exposing the inner and the outer electrodes to an electrolyte solution; and

establishing a potential difference between the inner and the outer electrodes thereby to produce hydrogen by electrolysis, at least one of the inner and the outer electrodes including at least two generally tubular shaped formations positioned one within the other, immediately adjacent each other, and each of the generally tubular shaped formations are of a foraminous electrically conductive construction.

89. The method as claimed in claim 88, in which exposing the inner and the outer electrodes to an electrolyte solution includes exposing the inner and the outer electrodes to an acidic electrolyte solution.

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