



(19) **United States**

(12) **Patent Application Publication**
Symons et al.

(10) **Pub. No.: US 2002/0014413 A1**

(43) **Pub. Date: Feb. 7, 2002**

(54) **ELECTROLYTIC SYSTEM AND METHODS FOR SCREENING CATALYTIC MATERIALS**

(76) Inventors: **Peter G. Symons**, Williamsville, NY (US); **J. David Genders**, Elma, NY (US)

Correspondence Address:
Howard M. Ellis
SIMPSON, SIMPSON
& SNYDER, PLLC
5555 Main Street
Williamsville, NY 14221 (US)

(21) Appl. No.: **09/920,243**
(22) Filed: **Aug. 1, 2001**

Related U.S. Application Data

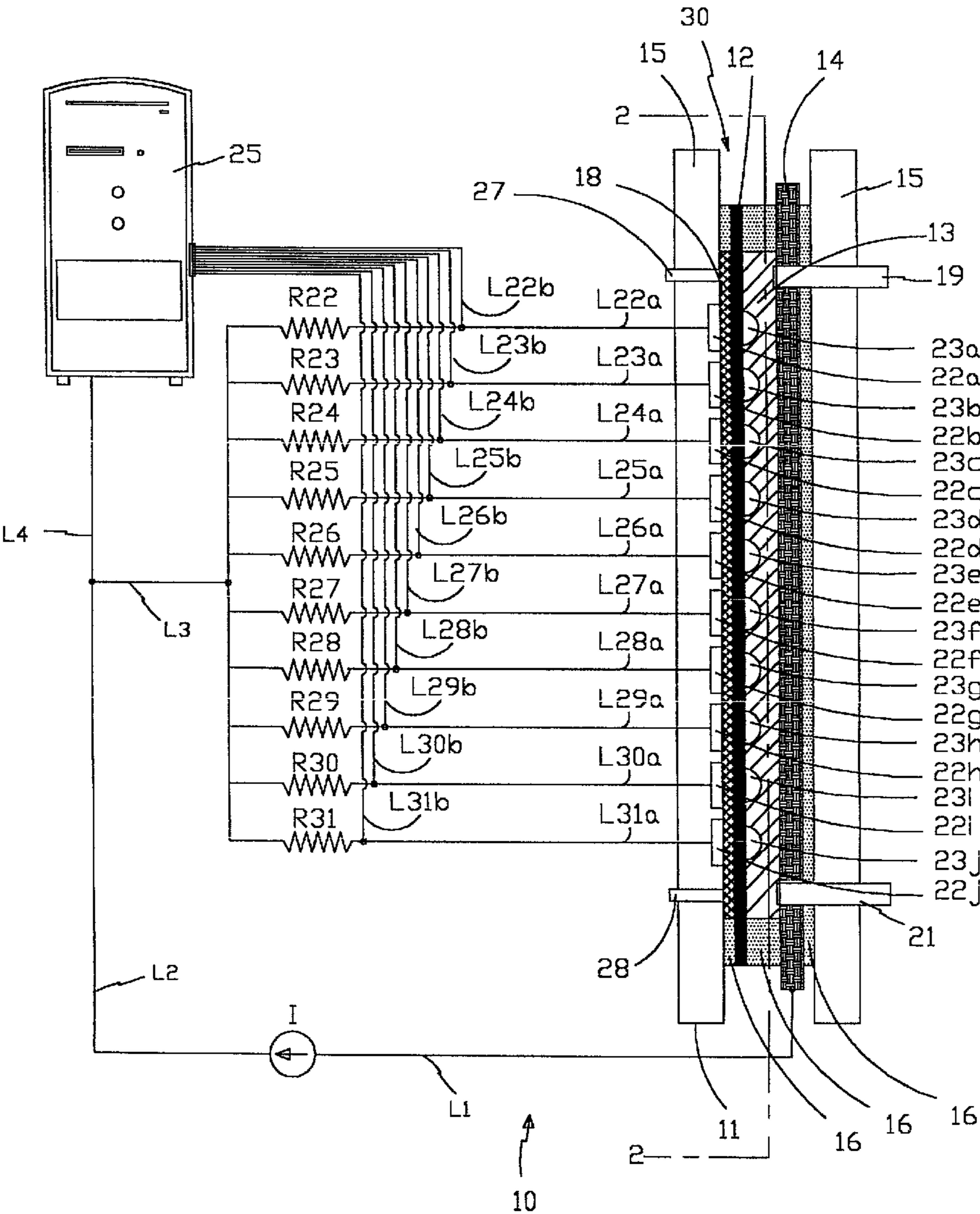
(63) Non-provisional of provisional application No. 60/223,238, filed on Aug. 4, 2000.

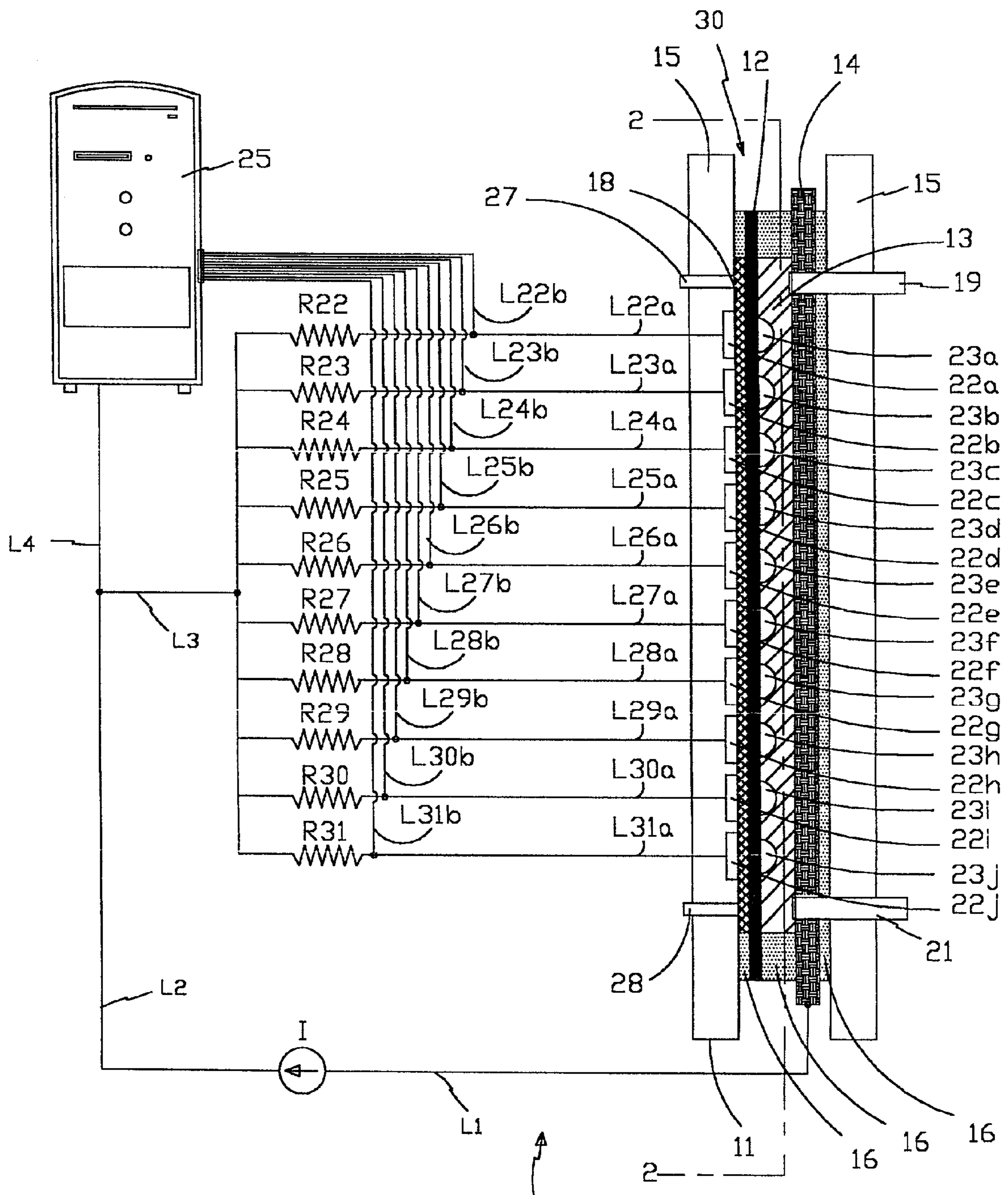
Publication Classification

(51) **Int. Cl.⁷** **C25D 21/12**; C25D 5/00; C25C 3/20
(52) **U.S. Cl.** **205/81**; 204/229.8

(57) **ABSTRACT**

A system for screening and measuring the effectiveness of catalysts, comprising an electrolytic cell having a counter electrode comprising a plurality of segmented anodes, each of the anodes electrically isolated from each other, and a catalyst support adapted for holding an associated plurality of cathodes, where each cathode is operatively arranged to function as a working electrode when a discrete catalyst is deposited thereon, wherein the catalyst support positioned between the counter electrode and the working electrodes, and, means for measuring current in each of the plurality of segmented anodes, where the current is an indication of effectiveness of each discrete catalyst.





10

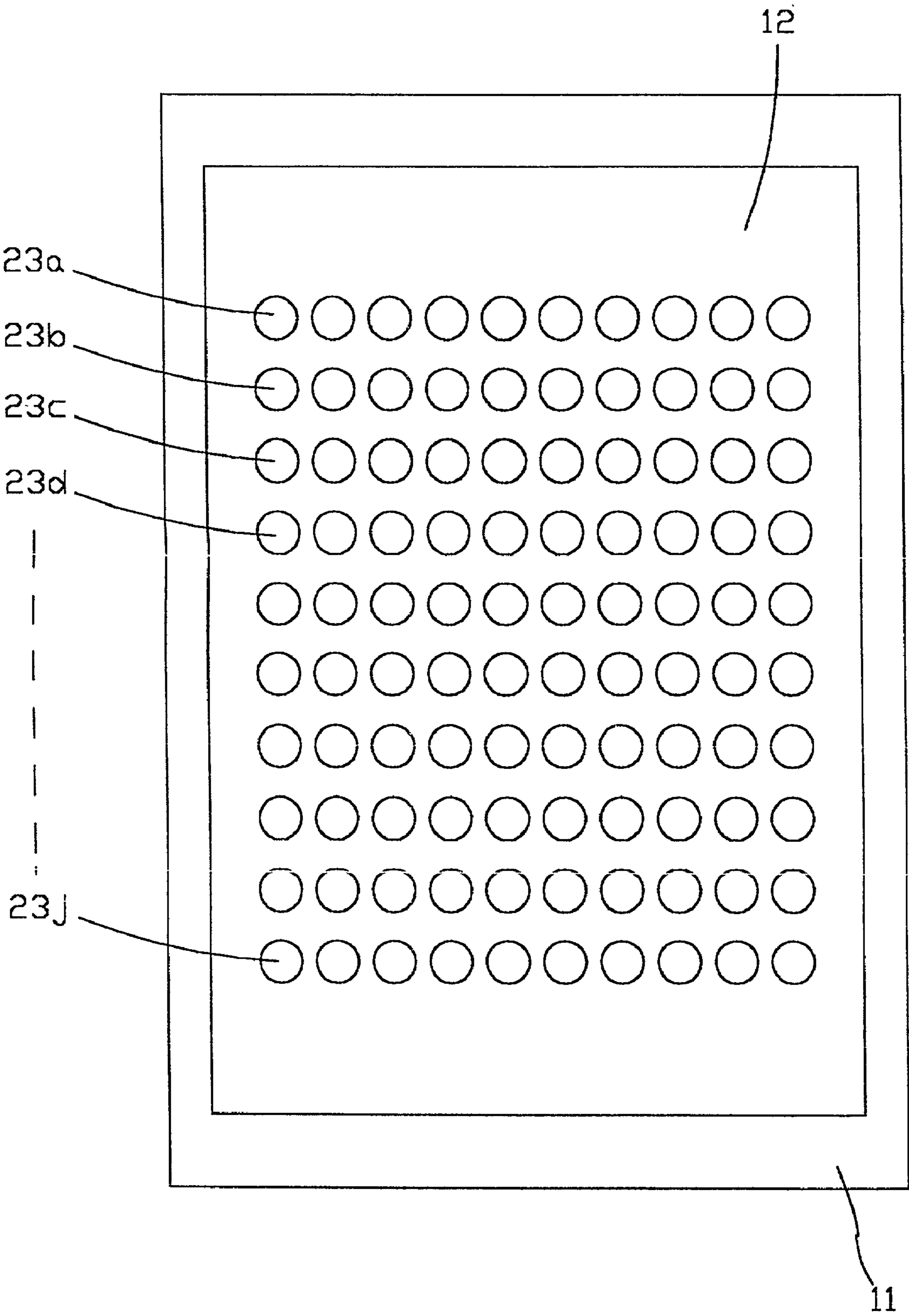


Fig. 2

ELECTROLYTIC SYSTEM AND METHODS FOR SCREENING CATALYTIC MATERIALS

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of U.S. provisional application Ser. No. 60/223,238, filed Aug. 4, 2000.

TECHNICAL FIELD

[0002] This invention relates generally to a novel apparatus and methods for screening the activity and measuring the effectiveness of catalytic materials, and more specifically, to an electrolytic apparatus and methods for simultaneously measuring and comparing the activities of a plurality of catalytic compositions for electrochemical applications, such as energy consuming cells, energy producing cells, e.g., fuel cells, and the like.

BACKGROUND OF THE INVENTION

[0003] In order to meet performance and cost targets for use in vehicles, the operating voltages of proton-exchange membrane fuel cells, for instance, must be increased. One significant barrier to higher voltages is the low activity of oxygen-reduction catalysts. New catalysts for proton exchange membrane (PEM) fuel cells, for example, are needed that possess higher activities than state-of-the-art precious metal catalysts, e.g., platinum metal alone. Possible approaches may include the development of improved precious metal electrode structures, precious metal alloy catalysts, non-precious metal catalysts, development of improved systems for screening new catalytic materials, and so on.

[0004] Fuel cells are attractive because of their potentially high-energy conversion efficiencies, modular design, and their environmental aspects, i.e., generating very low levels of chemical and acoustical pollution. However, their power density needs to be increased so the weight and size of the fuel cell can be decreased. A major shortcoming is that low temperature fuel cells, i.e., those operating at temperatures as low as 80° C., like the phosphoric acid fuel cell (PAFC) and PEM fuel cell experience a decrease in power and energy conversions due to poor reduction kinetics at the cathode where protons react with an oxygen source, such as air to form water in accordance with following reaction:



[0005] More particularly, in the case of the PEM fuel cell, the high overpotential at the cathode is viewed as the most important source of energy loss. The slow kinetics of the reduction of molecular oxygen to water (I) has been found to contribute significantly to losses in overall cell voltage, i.e., up to 500 mV at 1 A/cm² when air is used as the oxidant. While more current state-of-the-art catalysts with reduced loadings of 0.15 mg of Pt/cm² are capable of providing power densities equivalent to about 1 g of Pt/kW, which previously could only be achieved with catalyst loadings in the range of 8 mg Pt/cm², platinum metal on its own generally is not expected to be able to achieve the needed higher power densities in low temperature fuel cells.

[0006] Progress in higher power densities has been made by improving catalyst utilization in PEM fuel cells. Platinum metal loadings thirty (30) times lower than earlier related

catalyst systems have been developed. One method included the use of solid polymer (ionomer) electrolytes providing both the medium for bulk proton and the interfacial environment for the reaction. Thus, improvements in catalyst utilization were achieved by making more of the platinum based catalysts accessible to this interface, i.e., membrane-electrode composite/solid polymer electrolyte. Other methods have included bonding platinum black catalysts to the membrane of a solid polymer electrolyte by hot pressing mixtures of metal powder and binder.

[0007] Other efforts at improving catalyst layer utilization have included gas diffusion electrodes. Applying catalyst inks to the membrane appears to offer several advantages in higher catalyst utilization, namely greater durability and longer term performance. Binary alloys of Pt—X have been found to improve the overpotential of oxygen reduction at the cathode. Mukerjee, et al, *Electroanal. Chem.*, 357, 201 (1993) have demonstrated enhanced activity of platinum alloy catalysts, such as Pt—Ni, Pt—Co and Pt—Cr. Other studies in the field have shown certain platinum based alloys to offer the greatest activation over other precious metals, and in some instances better activity than platinum/ruthenium alloys. Overall, studies have shown the best elements found in decreasing order are: Pt, Pd, Tr, Rh, Ru and Os.

[0008] Thus far, only catalysts having binary systems have been investigated to any substantial degree, especially in view of the ever-increasing number of possibilities to be considered when extending out evaluations to ternary and quaternary catalyst systems. To illustrate the number of possible combinations: at a resolution of 11 different compositions, ranging from 0%, 10%, . . . 90%, 100%, along each binary edge the number of combinations increases from 11 to 66 to 286 to 1001, when allowing for 2, 3, 4 and 5 elements in the combination, respectively.

[0009] Consequently, the time consuming and uneconomical serialized approach of evaluating the activity of so many potentially useful catalyst combinations individually has slowed the rate of progress in identifying more active catalysts for electrochemical cells in general, and especially, electrocatalysts for use in fuel cells.

[0010] One new screening method was recently developed by Reddington et al, *Science*, 280, 1735 (1998), for identifying electrocatalysts for use in a methanol oxidation fuel cell. In this work, a 645 member array was studied containing mixtures of five elements. A four member quaternary catalyst demonstrated 40% higher activity than the previous best catalyst even though the quaternary catalyst had only half the surface area. This work made use of a color printer to intimately and accurately mix varying concentrations of catalysts and print them on carbon paper. The method employed inks containing transition metal salts adjusted to an appropriate viscosity with glycerol.

[0011] While this method did show the advantages of combinatorial electrochemistry for measuring the catalytic activity in a methanol fed fuel cell, i.e., oxidation of methanol at the anode, wherein the fluorescence of protons was an indicator of performance, it was found that the apparatus and methodology was not a reliable indicator of the performance of electrocatalysts in other types of cell environments. For example, the cell design did not provide the interfacial environment for the reaction, or possess the well defined geometry to emulate the electrochemistry of the oxygen

reduction reaction in the presence of a solid polymer electrolyte of a PEM fuel cell with no added liquid electrolyte. Moreover, only initial reaction rates could be investigated as the proton diffusion zones overlapped which blurred the fluorescence associated with an individual catalyst.

[0012] Accordingly, there is a need for an improved system and method for efficiently screening a plurality of catalytic materials prepared by various methodologies, such as combinatorial chemistry. More specifically, there is need for a system which includes, inter-alia, an electrolytic cell possessing a geometry and interfacial environment which is sufficiently universal, or can be readily adapted, so that data generated on the activity of members of a given catalyst library can be extended to a wide range of both energy producing and energy consuming electrolytic cells. Such screening systems should include electronic, and preferably computer assisted means for measuring and comparing the activity of a plurality of catalytic materials simultaneously.

SUMMARY OF THE INVENTION

[0013] It is therefore a principal object of the invention to provide a more efficient and economic electrochemical system and method for screening and measuring the activity of a plurality of catalytic materials, simultaneously. The system comprises a novel apparatus, and methods of use for rapidly measuring and comparing activities of a plurality of catalytic materials deposited on a support structure. More particularly, the apparatus provides for application of multiple catalysts to a common substrate in a predetermined pattern or array. The system and methods thus provide the added benefit of requiring but a single electrical connection, one time for screening large numbers of catalytic materials, simultaneously. In addition, the improved methods and apparatus disclosed herein provide for screening catalysts in an electrolytic cell, i.e., in an environment and under reaction conditions closely analogous to the conditions catalysts will be employed. Hence, the system and methods provide not only more efficient and economic screening of catalytic materials, but the data generated will be more predictable in terms of future performance in cell environments, and therefore, more reliable.

[0014] In general, the system of the invention relates to an integrated apparatus comprising in combination an electrolytic cell having a counter electrode structure subdivided into a plurality of segmented anodes. Each of the anodes is electrically isolated from the other. In addition, the electrolytic cell is equipped with a catalyst support adapted for holding an associated plurality of cathodes. The cathodes are operatively arranged to function as working electrodes when a discrete catalyst is deposited on the catalyst support. The catalyst support is positioned between the counter electrode and working electrodes.

[0015] In addition to the electrolytic cell, in a preferred embodiment, the system also comprises a circuit having a plurality of resistors connected in parallel, where each resistor in the circuit is connected to one of the plurality of segmented anodes. The system also includes means for measuring voltage across each of the plurality of resistors to calculate current therein, where the current is an indication of effectiveness of each discrete catalyst. It should be apparent that any other suitable means of measuring current through the cathodes (e.g., ammeters) could also be used.

[0016] Significantly, the system enables each anodic segment to independently measure the electrical activity of the catalytic material perpendicular to its surface.

[0017] While the above system has been described in conjunction with an electrolytic cell specifically configured for screening a multiplicity of materials as catalytic coatings intended for use as cathodes, the invention likewise contemplates screening electrocatalysts intended for use as anodic coatings. In the latter case, the counter electrode of the electrolytic cell would be subdivided into segmented cathodes and a multiplicity of discrete catalytic coatings would be applied to a common catalyst support as individual working anodes. The pattern of the discrete catalytic coatings on the anodic support would in-turn be positioned in proximity to the subdivided segmented cathode.

[0018] More specifically, the system for screening and measuring the effectiveness of catalysts may comprise an electrolytic cell having a counter electrode comprising a plurality of segmented cathodes. Each of the cathodes is electrically isolated from each other. Also included is a catalyst support adapted for holding an associated plurality of anodes, where each anode is operatively arranged to function as a working electrode when a discrete catalyst is deposited on the catalyst support. The catalyst support is positioned between the counter electrode and the working electrodes. In a preferred embodiment, the system further contains a circuit comprising a plurality of resistors connected in parallel, where each resistor in the circuit is connected to one of the plurality of segmented cathodes, and means for measuring voltage across each of the plurality of resistors to calculate current therein, where the current is an indication of effectiveness of each discrete catalyst. Again, any other suitable means of measuring current through the cathodes could be employed, such as ammeters connected in series with the cathode segments. In a preferred embodiment, an external constant current source powers the system, but it should be apparent to those having ordinary skill in the art that the system could be powered by a constant potential source.

[0019] It is still a further object of the invention to provide a method for sensing and measuring effectiveness of catalysts by simultaneously measuring current in a plurality of anode segments associated with the catalysts.

[0020] This aspect of the invention contemplates an electrolytic cell having a plurality of catalytic materials where each of the catalysts is associated with an electrode. The method of screening the catalysts is performed by the steps comprising: passing a current through the electrolytic cell where the current is divided between the plurality of catalysts and their associated electrodes, and then measuring current passing through each of the electrodes. The method may be practiced wherein the current is arranged to pass simultaneously through each of the plurality of catalysts and their associated electrodes. The current may be produced by either a constant current or constant potential source.

[0021] The invention further provides for a method for simultaneously identifying the activity of a plurality of catalytic materials by a method which comprises the steps of: (i) depositing onto a common substrate or support of an electrolytic cell of a catalyst screening system, a plurality of discrete catalytic materials to form a cathode as a working electrode. The electrolytic cell further comprises a counter

electrode structure subdivided into a plurality of segmented anodes, wherein each of the anodes is electrically isolated from the other. Each of the discrete catalysts deposited onto the common catalyst support or substrate is positioned in proximity with its own segmented anode. The common catalyst support is positioned between the counter electrode and the working electrode. The catalyst screening system further comprises an electrical circuit having a plurality of resistors connected in parallel with the plurality of segmented anodes. (Alternatively, ammeters or other current measuring means could be used to measure current in the segmented anodes, in lieu of the resistive network.) Data acquisition and computer means are connected to the circuit for sensing and measuring the current in each anode segment. Accordingly, this method also includes the step of (ii) at least measuring current in each of the plurality of segmented anodes, where the current measurement is indicative of catalyst activity.

[0022] While the specific methods for preparation of the catalytic materials or workpiece for screening are not part of this invention, it will be understood that the catalytic materials for screening may be prepared by combinatorial chemistry, or other preparative methods familiar among persons of ordinary skill in the art.

BRIEF DESCRIPTION OF THE DRAWINGS

[0023] FIG. 1 is a side view of one embodiment of the apparatus of the invention, and of the associated electrical circuit and computer means; and,

[0024] FIG. 2 is a view of the embodiment shown in FIG. 1, taken generally along line 2-2 in FIG. 1.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0025] It should be appreciated at the outset that like drawing reference numbers on the two drawing figures represent identical structural elements of the present invention. It should also be appreciated that, while in a preferred embodiment, an apparatus having 100 segmented anodes, and the same number of associated catalytic coatings and measuring resistors is illustrated and described herein, this embodiment is intended to be illustrative only and not limiting. For example, the present invention, its system, apparatus and method, provides a novel means of measuring catalytic activity in a system having a plurality (i.e., two or more) catalysts.

[0026] Adverting to FIG. 1, illustrated is a catalyst screening system 10 for determining the activity of electrocatalysts deposited onto an internal surface of electrolytic cell 30, shown in modular configuration. Advantageously, the activity of catalytic coatings, according to the immediate invention can be performed either at the anode or cathode of the electrolytic cell, depending on the intended application of the catalyst material. Cell 30 is of universal or generic configuration capable of emulating the performance of catalytic materials used either in energy producing or energy consuming cells. Similarly, cell 30 of the catalyst screening system 10 enables evaluating the activity of a large number of electrocatalysts simultaneously intended either as anodic or cathodic coatings. Importantly, the universal configuration of the electrolytic cell mimics the actual working conditions in screening electrocatalysts, for more reliable activity data.

[0027] More specifically, cell 30 may perform as a power producing cell emulating a PEM type fuel cell, phosphoric acid fuel cell, or other proton generating type fuel cell, for example. Protons from hydrogen or mineral acid, like sulfuric acid, phosphoric acid, or practically any other hydrogen-rich substance, such as natural gas, alcohols, e.g., methanol, ethanol (with use of a reformer), is introduced through fuel inlet 27 into the anode side of the cell, and exiting fuel outlet 28. In completing the reaction and circuit, cell 30 also requires an oxidant, such as air or oxygen introduced through gas inlet 19 where the working electrodes comprising the various catalytic materials being screened as cathodes facilitate the conversion of protons and oxygen into water for exiting the cell at outlet 21. At the working electrode side the configuration of test cell 30 is sufficiently universal that it emulates the performance of any fuel cell generating protons at the anode, plus electrons to provide an electrical current directed outside the cell for performing work. As a power consuming device, cell 30 is also capable of screening catalysts compositions employed in the synthesis of a chemical product, such as hydrogen peroxide.

[0028] Electrolytic cell 30 employs a subdivided counter electrode 22. When counter electrode 22 is operating as an anode, the anode is segmented into a plurality of mutually distinct, electrically isolated, mini-electrodes 22a, 22b, 22c, . . . 22j. As anodes, the segmented counter electrodes 22a, 22b, 22c, . . . 22j may be prepared from carbons, e.g., cloths, papers, especially if one wishes to pass gases through the counter electrode compartment. Preferred counter electrodes also include graphites, such as graphite rod, for example. As one preferred embodiment, electrodes 22 of cell 30 are comprised of titanium coated with Pt as the segmented counter electrodes. Depending on the working environment, however, other deposited metals may be used, such as Au, Ag, Sn, Pb, Cu, and so on. In addition, anode catalyst coatings, such as Pt—Ru can be applied to the segmented structures for facilitating the formation of protons, for example. Typical catalyst loadings may be in the range of about 1 to 10 mg/cm², and more preferably, from about 2 to 5 mg/cm².

[0029] Cell 30 comprises current carrier 12, preferably a cell separator type structure, and more specifically, a non-porous ion-exchange material. The membranes are generally water and gas permeable, thin, continuous, permselective cationic exchange membranes, allowing the transport of mainly positively charged protons from the anode side of the cell to the cathode side, i.e., proton exchange membrane. This would include such representative commercially available cationic polymers as E.I. DuPont's Nafion® brand perfluorosulfonic acid polymeric membranes, like Nafion 112, 115 and 117. Other representative polymeric membranes include Flemion® and Aciplex® brand perfluorosulfonic acid polymeric membranes from Asahi Glass, and Neosepta® brand perfluorinated membranes from Tokuyama Soda. Other representative examples of useful polymeric membrane materials include those having hydrocarbon backbones prepared from non-fluorinated polymers. Sulfonic acid groups are introduced onto their backbones for proton transport conductivity. A few representative examples include poly(styrene sulfonic acid), sulfonated poly(etheretherketone) or PEEK, sulfonated poly(phenylene sulfide), suylfonated poly(ethersulfone), poly-benzimidazole(PBI), and so on.

[0030] Catalyst samples **23a**, **23b**, . . . **23j** are conveniently deposited onto the surface of the current carrier, or membrane **12** to form membrane electrode assemblies (MEA). The MEA will usually be in the form of a composite type structure, or solid polymer electrolyte.

[0031] The present system may be used in screening virtually any type of catalytic material, both precious and non-precious metals, including homogeneous and heterogeneous compositions, single metals or mixtures in varying percentages. Precious metals may include Pt, Pd, Ir, Rh, Ru, Os, Au, Ag and mixtures thereof. This would include preparation of catalysts from salts like $\text{RhCl}_3 \cdot x\text{H}_2\text{O}$, OsCl_3 , HAuCl_4 , AgNO_3 , and so on. Representative non-precious metals include Ni, Co, Cr, Al, Ti, Pb, Fe, Cu, Zn, Cd, Sn, and so on. Catalysts of this type can be prepared from salts like $\text{NiCl}_2 \cdot 6\text{H}_2\text{O}$; $\text{Co}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$; $[\text{Cr}(\text{H}_2\text{O})_4\text{Cl}_2] \cdot 2\text{H}_2\text{O}$; $\text{Al}(\text{NO}_3)_3 \cdot 9\text{H}_2\text{O}$; TiCl_4 ; $\text{Pb}(\text{NO}_3)_2$, $\text{FeCl}_2 \cdot 4\text{H}_2\text{O}$; $\text{Cu}(\text{NO}_3)_2 \cdot 6\text{H}_2\text{O}$; $\text{CdCl}_2 \cdot x\text{H}_2\text{O}$, to name but a few.

[0032] Generally, a catalyst array can be prepared for screening by any of the methods practiced in the art. The tasks of identification and selection of specific catalysts for screening, methods of preparation and deposition are all concepts generally known among ordinary skilled artisans, and are well documented in the literature. While specific methods for preparation of catalysts are not part of this invention, the methods used should be capable of rapidly producing small scale quantities of the potentially useful catalysts in a format suitable for the system. One preferred technique would include combinatorial electrochemistry. One method of combinatorial electrochemistry involves the use of an inkjet type printer as described by Reddington, et al., page 1736 *infra*. Another convenient combinatorial process which may be employed in depositing catalysts onto a surface of a membrane for use in the methods disclosed herein is the so called "pipette method" which includes the steps of covering the membrane with a suitable template; dividing the area of a membrane into a plurality of independent reservoirs, e.g., 100. Metal salt solutions are prepared at a predetermined concentration, e.g., 5 mg/ml $\text{H}_2\text{PtCl}_6 \cdot 6\text{H}_2\text{O}$; $\text{K}_2\text{Ru}(\text{OH})(\text{NO}_2)_4\text{Cl}_6$, $\text{RhCl}_x \cdot \text{H}_2\text{O}$ or K_2PdCl_6 and pipetted into each reservoir at a particular volume, e.g., 0 (none of that metal), 5, 10 . . . 50 μl (pure metal) of each metal salt solution and allowed to mix. The salt solutions are then treated with two 15 μl additions of a 1% solution of a reducing agent, like sodium borohydride to reduce the metals on the surface of the support. The methods of this invention will enable efficient screening of catalysts containing 1 or more elements, and more specifically, 1, 2, 3, 4 and 5, or more combinations.

[0033] Generally, the dimensions of the catalyst spots applied to the support for screening should be smaller than the area of the individual electrode (anode) segments such that the current attributable to the catalyst is independently measured by the segment. Thus, in practicing the invention the discrete catalysts may be deposited onto membrane (support) **12** or other catalyst support in a pattern such as that illustrated by **FIG. 2**, so when support **12** is placed in the cell each catalyst spot will be positioned opposite to a single anode segment **22a** . . . **22j**. For example, with reference to **FIG. 1**, it is seen that catalyst spot **23a** is associated with anode segment **22a**. By "associated" we mean that the catalyst spot is positioned proximate a certain anode segment such that activity of the catalyst spot will affect current

in the anode segment. In a preferred embodiment, each catalyst spot is aligned with a corresponding, or associated, anode segment such that current due to a specific catalyst spot passes through a corresponding segment of the anode. This is made possible by making the dimensions of the anode segments large relative to the surface area of the electrocatalysts and in comparison to the distance between anode and cathode. These requirements are readily met because of the small size of the catalyst spots and the thin dimensions of the membrane assembly. It should be appreciated, however, that variations in dimensions of both the anode segment and catalyst spot are possible, and can be readily appreciated by those having ordinary skill in the art, and the appended claims are not intended to be limited to particular dimensions, or even ratios of dimensions.

[0034] In a preferred embodiment, to complete the circuit internally, electrolytic cell **30** includes conductive carbon felt blanket **13** positioned between current collector **14** and the catalyst spots **23a**, **23b**, . . . **23j** deposited on membrane support **12**. On the anolyte side of the cell an optional mesh blanket **18** comprised of a polymeric material may be positioned between the segmented counter electrodes and the MEA as a turbulence promoter. Blanket **18** may in some instances be omitted where, for example, a gas is passed through anolyte compartment, in which case it would be desirable to have segmented carbon felt electrodes in engagement with membrane **12**. The cell is sealed to avoid leakage of fuel and oxidant with the aid of gaskets **16** and closed with end frame members **15** and bolts or clamps of conventional design (not shown).

[0035] In operating the system a source of acid or other proton yielding substance, e.g., nitric acid, hydrogen, is fed to cell **30** via inlet **27**. Simultaneously, an oxidant, e.g., air or oxygen is fed to the cathode side of the cell via inlet **19**.

[0036] External to the electrolytic cell is a circuit comprising a plurality of resistors R_{22} , R_{23} , R_{24} . . . R_{31} connected in parallel, where each resistor in the circuit is connected to a corresponding segmented anode. In other words, resistors R_{22} , R_{23} , R_{24} . . . and R_{31} are connected to segmented anodes **22a**, **22b**, **22c**, . . . **22j**, respectively. The bank of resistors are connected at their common node to current collector **14** of electrolytic cell **30** via leads **L1**, **L2** and **L3**, and are in turn connected to a data acquisition means, not shown but located in computer **25**, via lead **L4**. The remaining nodes of the individual resistors are connected to the data acquisition means via leads **L22a**, **L22b**, **L22c**, . . . **L22j**, respectively. The data acquisition means functions to measure the voltage across each resistor, and then calculates the current through each resistor using Ohm's law ($V=IR$). The current through each resistor, of course, corresponds to the current through the resistor's corresponding segmented anode, and its associated catalyst spot. For example, the current through resistor R_{22} corresponds to the current through catalyst spot **23a**, etc. In a preferred embodiment, current source **I** was adjusted and regulated to provide a constant DC current of 2 amperes. Resistors R_{22} , R_{23} , R_{24} . . . and R_{31} were each 200Ω at 5% tolerance. Obviously, the lower tolerance resistors used, the more accurate the results. Thus, it is seen that a simple parallel resistive network enables measurement of the activity of a plurality of catalysts simultaneously, by virtue of simple current division and Ohm's law calculations. It should be appreciated by those having ordinary skill in the

art that other means, besides a parallel resistive network, could be used to measure the current in each catalyst/electrode. For example, ammeters could be arranged in series with the electrode catalysts.

[0037] In a preferred embodiment, a general purpose PC 25 was used to house the data acquisition system (DAS) and process the acquired data. To obtain 100 current readings, the data acquisition system used comprised quantity two (2) model CIO-DAS6402 High Speed 64-Channel Analog Input Board, installable in the ISA-bus slot of the PC. The DAS was manufactured by Measurement Computing Corporation, 16 Commerce Blvd., Middleboro, Mass. 02346, and distributed by Omega Engineering, One Omega Dr., Stamford, Conn. 06907. As is well known in the art, the DAS turns a PC into a high-speed data acquisition and control station suitable for laboratory data collection. The board converts the analog input signals into digital signals for processing and display by the computer. The on-board 1024 sample FIFO buffer collect the results of analog/digital (A/D) conversions and stores them until the computer's CPU is able to transfer the data into PC memory. The FIFO buffer allows the PC to store up the A/D transfer requests, then services the requests in batches. The FIFO enables full data acquisition rates under multitasking operating systems like Windows. The connections to each DAS were made through separate 100-pin high-density connector. The CIO-DAS6402 includes a complete test and calibration program, which provides a step-by-step procedure for installing and configuring the card. It also creates a configuration file used by the optional Universal Library. The Universal Library is a set of I/O libraries and drivers for those users creating their own custom programs. The Universal Library is compatible with most DOS and Windows based languages and support the entire CIO family of boards. The Library includes an extensive set of programming examples written in Visual Basic, C and Pascal for both Windows and DOS languages. Although, in a preferred embodiment, a sophisticated DAS was used to measure the voltage drops across the resistors, it should be apparent that a cruder measurement system could be used. For example, although very simple and crude, voltmeters could be used to measure the voltage drops across the resistors.

[0038] Thus, it is seen that the objects of the invention are efficiently obtained, although modifications and changes to the invention may be readily appreciated by those having ordinary skill in the art, and these modifications are intended to be within the scope of the appended claims.

We claim:

1. A system for screening and measuring the effectiveness of catalysts, comprising:

- a) an electrolytic cell having a counter electrode comprising a plurality of segmented anodes, each of said anodes electrically isolated from each other, and a catalyst support adapted for holding an associated plurality of cathodes, where each said cathode is operatively arranged to function as a working electrode when a discrete catalyst is deposited on the catalyst support, wherein said catalyst support positioned between said counter electrode and said working electrodes;
- b) a circuit comprising a plurality of resistors connected in parallel, where each resistor in said circuit is connected to one of said plurality of segmented anodes; and,

c) means for measuring voltage across each of said plurality of resistors to calculate current therein, where said current is an indication of effectiveness of each said discrete catalyst.

2. The system recited in claim 1 further comprising data acquisition means to communicate said voltage measurements to a computer.

3. The system recited in claim 1 further comprising a general purpose computer specially programmed to receive data from said data acquisition means, process said data, and display information related to one or more of said catalysts.

4. The system recited in claim 1 wherein said means for measuring voltage comprises a voltmeter.

5. The system recited in claim 1 wherein said means for measuring voltage is a data acquisition means.

6. The system of claim 1 wherein said electrolytic cell emulates an energy producing cell.

7. The system of claim 1 wherein said electrolytic cell emulates an energy consuming cell.

8. The system of claim 6 wherein said energy producing electrolytic cell emulates a fuel cell.

9. The system of claim 8 wherein said fuel cell emulates a proton exchange membrane fuel cell.

10. The system of claim 8 wherein said fuel cell emulates a phosphoric acid fuel cell.

11. The system of claim 7 wherein said energy consuming cell emulates an electrolyzer for synthesis of a chemical product.

12. The system of claim 1 wherein said catalyst support of the electrolytic cell comprises a current carrier.

13. The system of claim 12 wherein said current carrier is an ion exchange membrane.

14. The system of claim 12 wherein at least said current carrier and discrete catalysts of said electrolytic cell form a membrane electrode assembly.

15. The system of claim 14 wherein said membrane electrode assembly of said electrolytic cell is a solid polymer electrolyte.

16. The system of claim 14 wherein the membrane electrode assembly of said electrolytic cell comprises at least a proton exchange membrane and the cathode.

17. A system for screening and measuring the effectiveness of catalysts, comprising:

- a) an electrolytic cell having a counter electrode comprising a plurality of segmented cathodes, each of said cathodes electrically isolated from each other, and a catalyst support adapted for holding an associated plurality of anodes, where each said anode is operatively arranged to function as a working electrode when a discrete catalyst is deposited on the catalyst support, wherein said catalyst support positioned between said counter electrode and said working electrodes;
- b) a circuit comprising a plurality of resistors connected in parallel, where each resistor in said circuit is connected to one of said plurality of segmented cathodes; and,
- c) means for measuring voltage across each of said plurality of resistors to calculate current therein, where said current is an indication of effectiveness of each said discrete catalyst.

18. A system for screening and measuring the effectiveness of catalysts, comprising:

a) an electrolytic cell having a counter electrode comprising a plurality of segmented anodes, each of said anodes electrically isolated from each other, and a catalyst support adapted for holding an associated plurality of cathodes, where each said cathode is operatively arranged to function as a working electrode when a discrete catalyst is deposited on the catalyst support, wherein said catalyst support positioned between said counter electrode and said working electrodes;

b) means for measuring current in each of said plurality of segmented anodes where said current is an indication of effectiveness of each said discrete catalyst.

19. A method for simultaneously identifying the activity of a plurality of catalytic materials, which comprises the steps of:

(i) depositing onto a common catalyst support of an electrolytic cell of a catalyst screening system a plurality of discrete catalytic materials to form a cathode as a working electrode, said electrolytic cell further comprising a counter electrode structure subdivided into a plurality of segmented anodes, each of said anodes electrically isolated from the other, each of the discrete catalysts deposited onto said common catalyst support positioned to be associated with its own seg-

mented anode, said common catalyst support positioned between said counter electrode and said working electrode; said catalyst screening system further comprising an electrical circuit with a plurality of resistors connected in parallel with the plurality of segmented anodes, and data acquisition and computer means connected to the circuit for sensing, and (ii) measuring current in each of said plurality of segmented anodes, where said current measurement is indicative of catalyst activity.

20. In an electrolytic cell having a plurality of catalysts, where each of said catalysts is associated with an electrode, a method of screening said catalysts, comprising:

passing a constant current through said electrolytic cell, where said constant current is divided between said plurality of catalysts and their associated electrodes; and,

measuring current passing through each said electrode.

21. The method recited in claim 20 wherein said constant current is arranged to pass simultaneously through each of said plurality of catalysts and their associated electrodes.

* * * * *