

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
1 November 2007 (01.11.2007)

PCT

(10) International Publication Number
WO 2007/124011 A2

(51) International Patent Classification:
H01M 4/86 (2006.01) *H01M 8/10* (2006.01)
H01M 4/88 (2006.01)

(74) Agents: HERMANNNS, Karl, R. et al.; Seed Intellectual Property Law Group PLLC, Suite 5400, 701 Fifth Avenue, Seattle, Washington 98104-7064 (US).

(21) International Application Number:
PCT/US2007/009596

(81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(22) International Filing Date: 20 April 2007 (20.04.2007)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
11/408,787 21 April 2006 (21.04.2006) US

(71) Applicant (for all designated States except US): BALLARD POWER SYSTEMS INC. [CA/CA]; 9000 Glenlyon Parkway, Burnaby, British Columbia V5J 5J8 (CA).

(84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

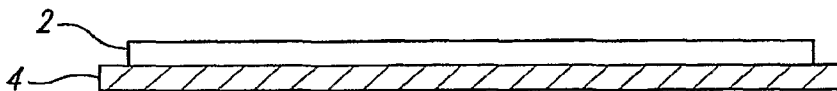
(72) Inventors; and

(75) Inventors/Applicants (for US only): MAH, Ronald [CA/CA]; 4838 Frances Street, Burnaby, British Columbia V5C 2S4 (CA). BAI, Kyoung, J. [CA/CA]; 2468 McLeary Crescent, Cranbrook, British Columbia V1C 5Y4 (CA). YE, Siyu [CA/CA]; 5683 Oakland Street, Burnaby, British Columbia V5H 1S2 (CA). DE HAAN, David, S. [US/CA]; 6089 Carson Street, Burnaby, British Columbia V5J 2Z8 (CA). VLAJNIC, Goran, R. [CA/CA]; #335 - 6198 Kathleen Avenue, Burnaby, British Columbia V5H 2S7 (CA). LEOW, Andrew [CA/CA]; 11481 95A Avenue, North Delta, British Columbia V4C 3V4 (CA).

Published:
— without international search report and to be republished upon receipt of that report

For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: METHODS OF MAKING COMPONENTS FOR ELECTROCHEMICAL CELLS



(57) Abstract: The present invention is related to methods of making membrane electrode assembly components. The methods include transferring a catalyst layer to a polymer electrolyte membrane or a gas diffusion layer. Methods of making membrane electrode assemblies with these components are also disclosed.



WO 2007/124011 A2

METHODS OF MAKING COMPONENTS FOR ELECTROCHEMICAL CELLS

CROSS-REFERENCE TO RELATED APPLICATION

This application claims the benefit under 35 U.S.C. § 119(e) of U.S. Provisional Patent Application No. 60/_____ filed April 21, 2006 (formerly U.S. Application No. 11/408,787, converted to provisional by Petition dated April 16, 2007), which provisional application is incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to methods of making components for electrochemical cells, in particular, catalyst-coated membranes, gas diffusion electrodes, and membrane electrode assemblies.

Description of the Related Art

Electrochemical fuel cells convert fuel and oxidant into electricity. Solid polymer electrochemical fuel cells generally employ a membrane electrode assembly that includes a solid polymer electrolyte membrane disposed between two electrodes. The membrane electrode assembly is typically interposed between two electrically conductive flow field plates to form a fuel cell. These flow field plates act as current collectors, provide support for the electrodes, and provide passages for the reactants and products. Such flow field plates typically include fluid flow channels to direct the flow of the fuel and oxidant reactant fluids to an anode electrode and a cathode electrode of each of the membrane electrode assemblies, respectively, and to remove excess reactant fluids and reaction products. In operation, the electrodes are electrically coupled for conducting electrons between the electrodes through an external circuit. Typically, a number of fuel cells are electrically coupled in series to form a fuel cell stack having a desired power output.

The anode electrode and the cathode electrode each contain a layer of anode catalyst and cathode catalyst, respectively. The catalyst may be a metal, an alloy

or a supported metal/alloy catalyst, for example, platinum supported on carbon black. The catalyst layer typically contains an ion conductive material, such as Nafion[®], and, optionally, a binder, such as polytetrafluoroethylene. Each electrode further includes an electrically conductive porous substrate, such as carbon fiber paper or carbon cloth, for reactant distribution and/or mechanical support. The thickness of the porous substrate typically ranges from about 50 to about 250 microns. Optionally, the electrodes may include a porous sublayer disposed between the catalyst layer and the substrate. The sublayer usually contains electrically conductive particles, such as carbon particles, and, optionally, a water repellent material for modifying its properties, such as gas diffusion and water management.

One method of making membrane electrode assemblies includes applying a layer of catalyst to a porous substrate in the form of an ink or a slurry typically containing particulates and dissolved solids mixed in a suitable liquid carrier. The liquid is then removed to leave a layer of dispersed particulates, thereby forming an electrode. An ion-exchange membrane, such as a polymer electrolyte membrane, is then assembled with an anode electrode and a cathode electrode contacting opposite surfaces of the membrane such that the catalyst layers of the electrodes are interposed between the membrane and the respective substrate. The assembly is then bonded, typically under heat and pressure, to form a membrane electrode assembly. When sublayers are employed, the sublayer may be applied to the porous substrate prior to application of the catalyst. The substrate is commonly referred to as a gas diffusion layer or, in the case when a sublayer is employed, the combination of the substrate and sublayer may also be referred to as a gas diffusion layer.

Conventional methods of applying catalyst to gas diffusion layers to form gas diffusion electrodes include screen-printing and knife-coating. However, when applying low loadings of catalyst to a substrate to form a gas diffusion electrode, it is difficult to obtain a smooth, continuous catalyst layer (*i.e.*, no discontinuities across the layer) with a uniform thickness due to the surface roughness of the substrate. This can result in fuel cell performance and/or durability being comprised.

Alternatively, a layer of catalyst can be applied onto both surfaces of the polymer electrolyte membrane to form a catalyst-coated membrane, and then assembled

with porous substrates to form a membrane electrode assembly. For example, a catalyst slurry may be applied directly onto the membrane by microgravure coating, knife-coating, or spraying.

However, the use of a catalyst containing a catalytic material and a hydrophobic binder is desirable for fuel cell durability. As discussed in U.S. Patent No. 6,517,962, fuel cells in series are potentially subject to voltage reversal, a situation in which a cell is forced to opposite polarity by the other cells in series. This can occur when a cell is unable to produce the current forced through it by the rest of the cells. Damage due to voltage reversal can be mitigated by increasing the amount of water available for electrolysis during reversal, thereby using the current forced through the cell in the more innocuous electrolysis of water rather than the detrimental oxidation of anode components. By restricting the passage of this water through the anode structure and into the exhaust fuel stream, more water remains in the vicinity of the catalyst. This can be accomplished, for example, by making the anode catalyst layer impede the flow of water (either in the vapor or the liquid phase). For instance, the addition of a hydrophobic material such as PTFE and/or FEP to these layers will make them more hydrophobic, thereby hindering the flow of water through the anode. However, if these polymers are not sintered, they may not be sufficiently hydrophobic and may wash out of the catalyst layer over time. Using conventional methods of applying the catalyst layer directly to the membrane, the catalyst layer would have to be sintered with the membrane. However, sintering temperatures are usually higher than the thermal degradation temperature of the ionomer. For example, Nafion® membranes typically start to decompose at about 250°C. Thus, if the membrane is coated with the catalyst having a hydrophobic binder and then subjected to temperatures sufficient to sinter the hydrophobic binder (e.g., 330°C for PTFE), the ion-conducting and water uptake properties of the ionomer may be decreased or destroyed.

Accordingly, while advances have been made in this field, there remains a need for improved methods of making gas diffusion electrodes and catalyst-coated membranes. The present invention addresses this issue and provides further related advantages.

BRIEF SUMMARY OF THE INVENTION

Briefly, the present invention relates to methods of making components for electrochemical fuel cells.

In one embodiment, the method comprises: forming a first transfer
5 assembly, the first transfer assembly comprising a first catalyst layer comprising a first
catalytic material and a hydrophobic binder on a surface of a first release sheet; heating
the first catalyst layer to a sintering temperature of at least 250°C to form a sintered first
catalyst layer; transferring the sintered first catalyst layer to a first surface of a polymer
electrolyte membrane; and removing the first release sheet from the sintered first
10 catalyst layer after bonding.

In another embodiment, the method comprises: forming a diffusion
sublayer on a surface of a release sheet; forming a catalyst layer comprising a first
catalytic material on the diffusion sublayer; transferring the catalyst layer to a surface of
an ion exchange membrane; and removing the first release sheet from the diffusion
15 sublayer. In some embodiments, the catalyst layer may comprise a hydrophobic binder
or an ionomer.

In yet another embodiment, the method comprises: forming a first
catalyst layer comprising a catalytic material on a surface of a release sheet; forming a
first diffusion sublayer on a first surface of the first catalyst layer; forming a second
20 diffusion sublayer on a surface of a gas diffusion substrate; transferring the first
diffusion sublayer to the second diffusion sublayer; and removing the first release sheet
from the first catalyst layer to form a gas diffusion electrode.

These and other aspects will be evident upon reference to the attached
drawings and following detailed description.

25 BRIEF DESCRIPTION OF THE DRAWINGS

In the figures, identical reference numbers identify similar elements or
acts. The sizes and relative positions of elements in the figures are not necessarily
drawn to scale. For example, the shapes of various elements and angles are not drawn
to scale, and some of these elements are arbitrarily enlarged and positioned to improve
30 figure legibility. Further, the particular shapes of the elements, as drawn, are not

intended to convey any information regarding the actual shape of the particular elements, and have been solely selected for ease of recognition in the figures.

Figures 1A to 1D show a sectional view representing a series of steps for forming a catalyst-coated membrane according to a first embodiment of the present invention.

Figures 2A and 2B show a sectional view representing the steps for forming a catalyst-coated membrane according to a further embodiment of the present invention.

Figures 3A to 3C show a sectional view representing the steps for forming a catalyst-coated membrane according to yet a further embodiment of the present invention.

Figures 4A to 4E show a sectional view representing a series of steps for forming a gas diffusion electrode according to another embodiment of the present invention.

15 DETAILED DESCRIPTION OF THE INVENTION

Unless the context requires otherwise, throughout the specification and claims which follow, the word “comprise” and variations thereof, such as “comprises” and “comprising” are to be construed in an open, inclusive sense, that is as “including but not limited to”.

20 As used herein and in the appended claims, “sintering” means stabilization of the hydrophobic polymer, typically by heat treatment to temperatures greater than about 250°C. One skilled in the art will appreciate that sintering conditions will be different for different polymers. For example, suitable sintering conditions include sintering temperatures that range from about 330°C to about 420°C for polytetrafluoroethylene (“PTFE”), about 250°C to about 280°C for fluorinated ethylene propylene (“FEP”) and about 300° to about 310°C for perfluoroalkoxy (“PFA”).

25 In the present context, “loading” refers to the amount of material that is formed or applied to a substrate, and is usually expressed as the mass of material per unit surface area of the substrate.

As used herein, "homogeneous" means that the constituents are substantially uniformly dispersed in the mixture.

The present invention is related to methods of making membrane electrode assembly components by bonding catalyst layers to a polymer electrolyte membrane to form a catalyst-coated membrane ("CCM") or to a gas diffusion layer ("GDL") to form a gas diffusion electrode ("GDE").

According to a first embodiment of the present invention, a method of making a CCM is shown in Figures 1A to 1D. The method includes forming a catalyst layer 2 on a release sheet 4 to form a transfer assembly 6 (Figure 1A); heating catalyst layer 2 to a sintering temperature equal to or greater than about 250°C (Figure 1B) to yield a sintered catalyst layer 8; transferring sintered catalyst layer 8 to a membrane 10 (Figure 1C) at a suitable transfer temperature and/or pressure ("T/P"); and removing the backing layer (Figure 1D).

With reference to Figure 1A, catalyst layer 2 contains a catalytic material, such as a noble metal or compounds thereof, a supported noble metal, a supported noble metal compound, or combinations thereof. Catalyst layer 2 also contains a hydrophobic binder, such as PTFE, FEP, PFA, or combinations thereof, and preferably does not contain an ionomeric material. The constituents of the catalyst layer may first be dispersed in a suitable liquid carrier such as an alcohol, water, or combinations thereof, homogeneously blended to form a dispersion, and subsequently applied to the release sheet. In some embodiments, the dispersion may further include a dispersion-stabilizing substance, for example, a surfactant, such as Triton[®]-X or Tergitol, and/or a pore former, such as methylcellulose. Any method known in the art for applying a dispersion may be used, such as, but not limited to, knife-coating, screen-printing, slot die coating, microgravure coating, decal transferring, and spraying. In some embodiments, the liquid carrier may be removed or partially removed prior to sintering by, for example, evaporation. Alternatively, the liquid carrier may be removed during sintering.

Suitable release sheet materials should be inert, non-adhering, non-porous and heat-resistant to the highest temperature to which it will be subjected so that the release sheet does not deform and may be reused. In one example, the release sheet

is a metal sheet, such as a stainless steel plate with a 2SB finish, a K05 metal coating, or ceramic coating; an aluminum sheet; or a heat-resistant polymeric film, for example, a polyimide film such as Kapton®. If desired, the release sheet may be pre-treated with a release agent prior to forming layers thereon to facilitate removal of the release sheet
5 from the catalyst layer or diffusion sublayer after transferring. The release agent may be, an alcohol, such as a polyvinyl alcohol.

As shown in Figure 1C, sintered catalyst layer 8 is transferred to membrane 10 after sintering by applying heat and/or pressure (T/P). For most solid polymer electrolyte membranes, suitable transfer temperatures may range from about
10 90°C to about 200°C, and suitable transfer pressures may range from about 5 to about 40 bar. Preferably, the opposing surface of membrane 10 is supported by a support material 12 during transferring. Support material 12 should be inert, non-adhering, non-porous and heat-resistant to the highest temperature to which it will be subjected, and does not need to be the same material as release sheet 4 because the transfer
15 temperature is typically lower than the sintering temperature. For example, support material 12 may be a PTFE, polyethylene, polypropylene, or polyester film, such as Mylar®. Release sheet 4 and support material 12 are removed from the sintered catalyst layer after transferring to form a catalyst-coated membrane 16, as shown in Figure 1D.

20 Figures 2A and 2B are illustrations of a further embodiment of the present invention, wherein a diffusion sublayer 14 is formed on release sheet 4 (Figure 2A) and then a catalyst layer 2 is formed on diffusion sublayer 14 (Figure 2B), prior to sintering and transferring. Diffusion sublayer 14 contains an electrically conductive material, which may be fibrous or particulate. For example, the conductive material is
25 carbon or graphite, such as, but not limited to, carbon blacks, graphitized carbon blacks, flake graphites, spherical graphites, chopped carbon fibers, milled carbon fibers, carbon whiskers, carbon nanotubes, chopped graphite fibers, milled graphite fibers, graphite whiskers, and graphite nanotubes, or combinations thereof. In some embodiments, it may be desirable to incorporate a hydrophobic binder into the diffusion sublayer to alter
30 the water transport properties thereof and/or to improve adhesion between the layers. Diffusion sublayer 14 may be formed on release sheet 4 by dispersing the constituents

in a suitable liquid carrier and then applied thereon by methods described in the foregoing.

It is anticipated that the diffusion sublayer may help transfer the catalyst layer to the membrane. The inventors have discovered that when using prior art methods of directly transferring a catalyst layer to the membrane, incomplete transfer occurs (*i.e.*, a portion of the catalyst layer may remain on the release sheet after transferring), particularly when the catalyst layer thickness is low, for example, equal to or less than about 5 microns, and typically when the catalyst loading is low, for example, equal to or less than about 0.15 mg Pt/cm². Incomplete transfer of the catalyst layer is undesirable because it results in fuel cell performance loss, durability, and cost issues. However, by employing a diffusion sublayer between the release sheet and the catalyst layer, as shown in Figures 2A and 2B, the catalyst layer can be completely transferred to the membrane.

In other embodiments, a second catalyst layer 18 may be formed on an opposing surface of membrane 10 to form CCM 20, as shown in Figure 3A. Catalyst layer 18 may contain the same composition of materials as in catalyst layer 2 in similar or different amounts, or may contain a different composition of materials, for example, catalyst with an ionomer. A catalyst layer with an ionomer, such as a fluorinated- and/or hydrocarbon-based ionomer, may be beneficial for uses where improved ionic conductivity in the catalyst layer is desired. One of ordinary skill in the art will readily select a catalyst composition suitable for a given application.

In some embodiments, catalyst layer 18 may be transferred to membrane 10 in a similar manner to that as described in the foregoing (*i.e.*, forming catalyst layer 18 on a release sheet 22), either subsequently (Figure 3B) or simultaneously (Figure 3C). Optionally, a diffusion sublayer, such as the one described in Figures 2A and 2B, may also be transferred with catalyst layer 18 (not shown). Note that if catalyst layer 18 contains an ionomer, then the diffusion sublayer should be sintered prior to forming catalyst layer 16 thereon. In other embodiments, catalyst layer 18 can be directly applied to the membrane by any method known in the art, before or after transferring (not shown).

In further embodiments, the CCM of the foregoing embodiments may be assembled with GDLs and/or GDEs to form a membrane electrode assembly ("MEA"). For example, with reference to Figure 1D, a GDL may be placed adjacent catalyst layer 8 while a GDE may be placed adjacent an opposing second surface of membrane 10. Alternatively, with reference to Figure 3A, a GDL may be placed adjacent sintered catalyst layer 8 while another GDL may be placed adjacent catalyst layer 16. In either case, the assembled MEA may be subjected to a bonding temperature and/or bonding pressure to substantially bond each of the components together. One skilled in the art can readily determine suitable bonding temperatures, pressures, and duration.

According to another embodiment of the present invention, a method of making a GDE is disclosed. The method includes forming a catalyst layer 2 on a support material 12 (Figure 4A); forming a diffusion sublayer 14a on catalyst layer 2 to form a transfer assembly 24 (Figure 4B); forming an additional diffusion sublayer 14b on a diffusion substrate 26 to form a partial GDL 28 (Figure 4C); transferring diffusion sublayer 14a to diffusion sublayer 14b (Figure 4D); and sintering to form a GDE 30 (Figure 4E). Support material 12 may be removed before or after sintering (not shown).

Catalyst layer 2 preferably contains a hydrophobic binder and a catalytic material, such that described in the foregoing. Furthermore, diffusion sublayers 14a, 14b may contain the same constituents as described in previous embodiments. In this embodiment, diffusion sublayers 14a, 14b may have the same or different compositions, and may have the same or different loadings. In addition, the liquid carrier of catalyst layer 2 may be removed or partially removed prior to forming first diffusion sublayer 14a thereon.

Any suitable diffusion substrate material may be used, provided that it is electrically conductive and porous. Exemplary diffusion substrate materials include carbonized or graphitized carbon fiber non-woven mats such as, but not limited to, TGP-H-090 (Toray Industries Inc., Tokyo, Japan); AvCarb[®] P50 and EP-40 (Ballard Material Products Inc., Lowell, MA); and GDL 24 and 25 series material (SGL Carbon Corp., Charlotte, NC). The choice of porous substrates is not essential to the present invention and one of ordinary skill in the art will be able to select a suitable porous substrate for a given application. In some embodiments, the porous substrate may be

hydrophobized, such as by impregnating the substrate in a solution containing a hydrophobic binder, which is then dried and/or sintered prior to application of diffusion sublayer 14b, or simultaneously sintered with diffusion sublayers 14a, 14b and catalyst layer 2 after transferring.

5 Transferring conditions may be similar to those described in the foregoing embodiments. Furthermore, in some embodiments, the liquid carrier of first and/or second sublayers 14a, 14b is removed during transferring.

With reference to Figure 4E, catalyst layer 2 and diffusion sublayers 14a, 14b are sintered after transferring of diffusion sublayers 14a, 14b. Alternatively,
10 catalyst layer 2 and diffusion sublayers 14a, 14b may be separately sintered before transferring or simultaneously sintered during transferring (not shown). Again, support material 12 may be any of the materials described in the foregoing, so long as it is heat-resistant to the highest temperature to which it will be subjected (e.g., transferring or sintering temperatures, depending on when support material 12 is removed).

15 The inventors have discovered that when transferring a catalyst layer containing a hydrophobic binder to the GDL, incomplete transfer of the catalyst typically occurs, particularly when transferring thin catalyst layers. However, by directly applying first diffusion sublayer 14a on catalyst layer 2, transfer of catalyst layer 2 is improved. Furthermore, by applying a second diffusion sublayer 14b on
20 diffusion substrate 26 and removing the liquid carrier in first and/or second diffusion sublayers 14a, 14b during transferring, adhesion between diffusion sublayers 14a, 14b is also enhanced. As a result, catalyst layer 2 can be completely transferred and adhesion between each of the layers may be improved compared to conventional methods.

25 In further embodiments, GDE 30 may be assembled with a membrane and another GDE, or may be assembled with a CCM and GDL to form a MEA. For example, with GDE 30 may be assembled with membrane 10 such that the catalyst layer 8 contacts membrane 10 (not shown). Another GDE is then assembled adjacent the opposing surface of membrane 10 to form a MEA. Alternatively, GDE 30 may be
30 assembled with a CCM, such as the one shown in Figure 1D and a GDL adjacent

catalyst layer 8, to form a MEA (not shown). Again, the assembled MEA may be bonded, as described in the foregoing.

In any of the above embodiments, an adhesive layer may be employed between any of the layers prior to transferring, such as that described in U.S. Patent Application No. 2004/0258979. The adhesive layer may include an ionomer and, optionally, carbon and/or graphite particles. It is anticipated that the adhesive layer may improve adhesion and may enhance proton conductivity through the catalyst layer.

All of the above U.S. patents, U.S. patent application publications, U.S. patent applications, foreign patents, foreign patent applications and non-patent publications referred to in this specification and/or listed in the Application Data Sheet, are incorporated herein by reference, in their entirety.

While particular elements, embodiments, and applications of the present invention have been shown and described, it will be understood that the invention is not limited thereto since modifications may be made by those skilled in the art without departing from the spirit and scope of the present disclosure, particularly in light of the foregoing teachings.

CLAIMS

What is claimed is:

1. A method of making a component for an electrochemical fuel cell comprising:
 - forming a first transfer assembly, the first transfer assembly comprising a first catalyst layer comprising a first catalytic material and a hydrophobic binder on a surface of a first release sheet;
 - heating the first catalyst layer to a sintering temperature of at least 250°C to form a sintered first catalyst layer;
 - transferring the sintered first catalyst layer to a first surface of a polymer electrolyte membrane; and
 - removing the first release sheet from the sintered first catalyst layer after bonding.
2. The method of claim 1, wherein the first catalytic material comprises a noble metal, or alloys thereof.
3. The method of claim 1, wherein the hydrophobic binder is polytetrafluoroethylene, fluorinated ethylene-propylene, or combinations thereof.
4. The method of claim 1, wherein the first catalyst layer consists essentially of the first catalytic material and the hydrophobic binder.
5. The method of claim 1, wherein the sintering temperature is at least 330°C.
6. The method of claim 1, wherein the first release sheet is a polymeric film.

7. The method of claim 1, wherein transferring comprises subjecting the first sintered catalyst layer and the polymer electrolyte membrane to at least one of a transfer temperature and a transfer pressure.

8. The method of claim 1, further comprising forming an ionomeric layer on at least one of the first surface of the sintered first catalyst layer and the first surface of the membrane, prior to transferring.

9. The method of claim 1, further comprising:
forming a second catalyst layer comprising a second catalytic material on an opposing second surface of the polymer electrolyte membrane.

10. The method of claim 9, wherein the step of forming the second catalyst layer further comprising:
forming a second transfer assembly, the second transfer assembly comprising the second catalyst layer on a surface of a second release sheet;
transferring the second catalyst layer to the opposing second surface of the polymer electrolyte membrane; and
removing the release sheet from the second catalyst layer.

11. The method of claim 10, wherein the sintered first catalyst layer and the second catalyst layer are simultaneously transferred to the first and second surfaces of the polymer electrolyte membrane, respectively.

12. The method of claim 1, further comprising:
bonding a first gas diffusion layer to the first catalyst layer; and
bonding a gas diffusion electrode against an opposing surface of the polymer electrolyte membrane, the gas diffusion electrode comprising a second gas diffusion layer and a second catalyst layer, such that the second catalyst layer contacts the opposing surface, to form a membrane electrode assembly.

13. A method of making a component for an electrochemical fuel cell comprising:

forming a diffusion sublayer on a surface of a release sheet;

forming a catalyst layer comprising a first catalytic material on the diffusion sublayer;

transferring the catalyst layer to a surface of a polymer electrolyte membrane; and

removing the first release sheet from the diffusion sublayer.

14. The method of claim 13, wherein the diffusion sublayer comprises a carbon material, a graphitic material, or combinations thereof.

15. The method of claim 13, wherein transferring comprises subjecting the catalyst layer and the polymer electrolyte membrane to at least one of heat and pressure.

16. The method of claim 13, wherein the catalyst layer further comprises an ionomer.

17. The method of claim 13, further comprising:

bonding a first gas diffusion substrate to the diffusion sublayer;

and

bonding a gas diffusion electrode against an opposing surface of the polymer electrolyte membrane, the gas diffusion electrode comprising a second gas diffusion substrate, a second catalyst layer, and a second diffusion sublayer interposed therebetween, such that the second catalyst layer contacts the opposing surface, to form a membrane electrode assembly.

18. A method of making a component for an electrochemical fuel cell comprising:

forming a first catalyst layer comprising a catalytic material on a surface of a release sheet;
forming a first diffusion sublayer on a first surface of the first catalyst layer;
forming a second diffusion sublayer on a surface of a gas diffusion substrate;
transferring the first diffusion sublayer to the second diffusion sublayer; and
removing the first release sheet from the first catalyst layer to form a gas diffusion electrode.

19. The method of claim 18, wherein the first catalyst layer and the first diffusion layer further comprises a hydrophobic binder, and the method further comprises heating the first diffusion sublayer and the catalyst layer to a sintering temperature of at least 250°C.

20. The method of claim 18, wherein the second diffusion sublayer comprises a hydrophobic binder, and the method further comprises heating the second diffusion sublayer to a sintering temperature of at least 250°C.

21. The method of claim 18, wherein the first and second diffusion sublayers comprises a carbon material, graphitic material, or combinations thereof.

22. The method of claim 18, wherein the first and second diffusion sublayers are the same.

23. The method of claim 18, further comprising removing a liquid carrier of at least one of the first and second sublayers during transferring.

24. The method of claim 18, further comprising:

contacting the gas diffusion electrode against a first surface of a polymer electrolyte membrane such that the first catalyst layer faces the first surface;

contacting a second gas diffusion electrode against an opposing second surface of the polymer electrolyte membrane such that a second catalyst layer faces the second surface; and

bonding the gas diffusion electrodes to the polymer electrolyte membrane.

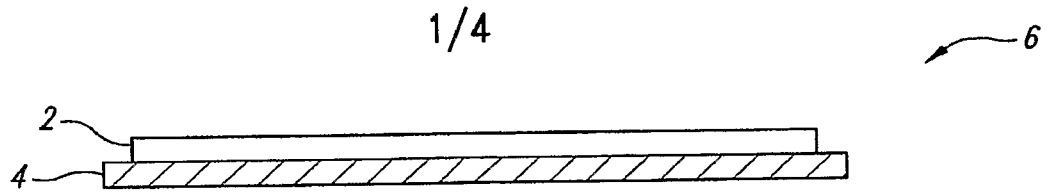


FIG. 1A

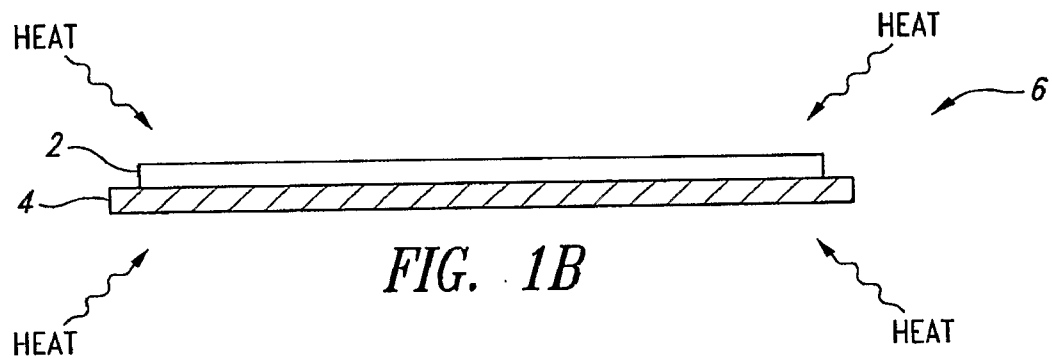


FIG. 1B

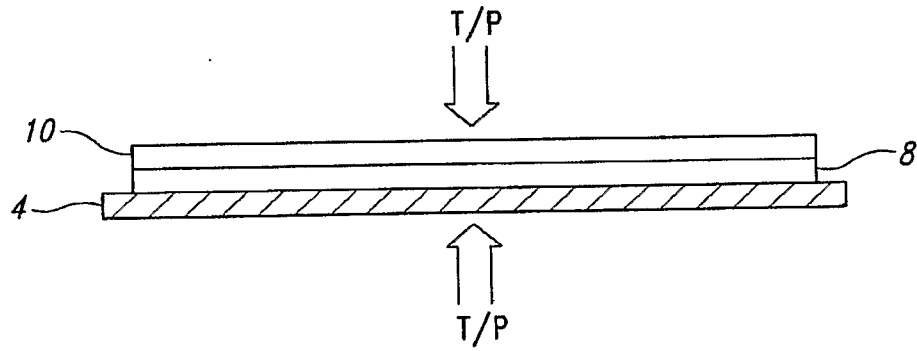


FIG. 1C

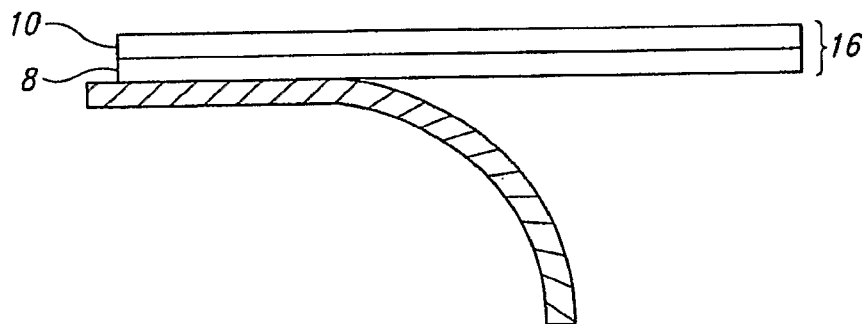


FIG. 1D

2/4

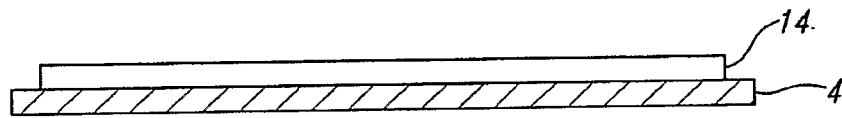


FIG. 2A

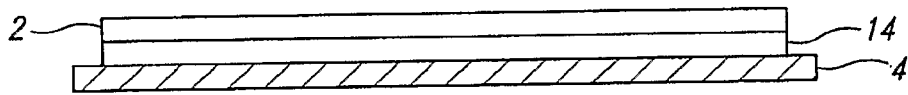


FIG. 2B

3/4

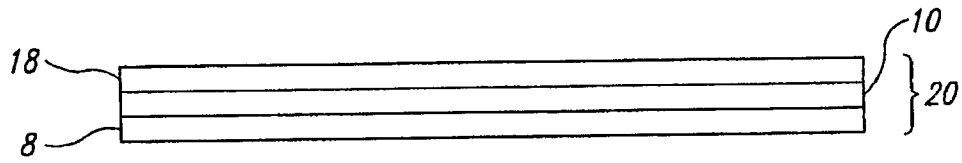


FIG. 3A

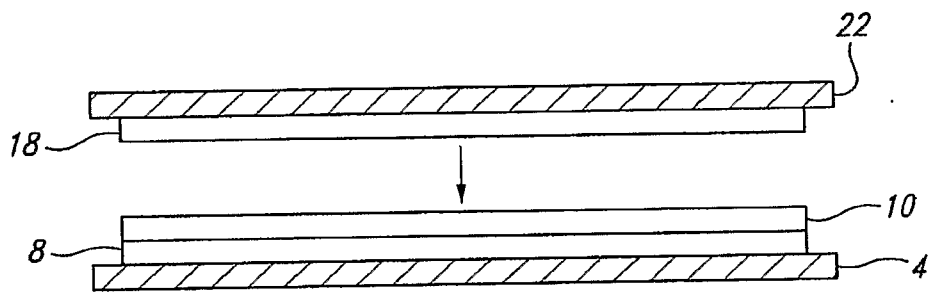


FIG. 3B

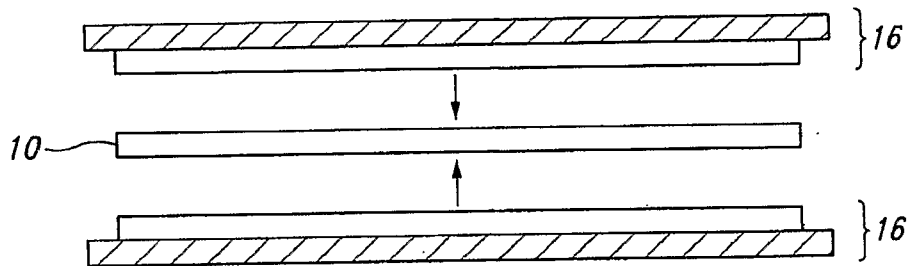


FIG. 3C

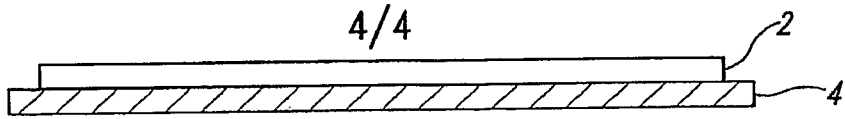


FIG. 4A

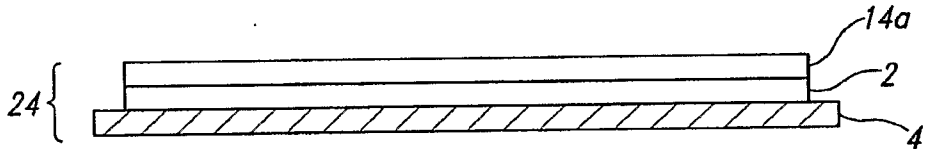


FIG. 4B

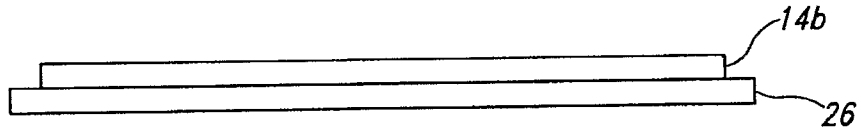


FIG. 4C

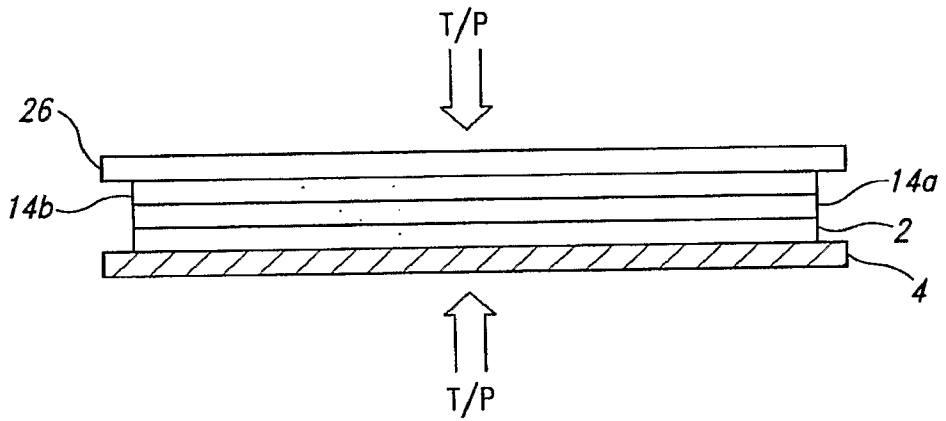


FIG. 4D

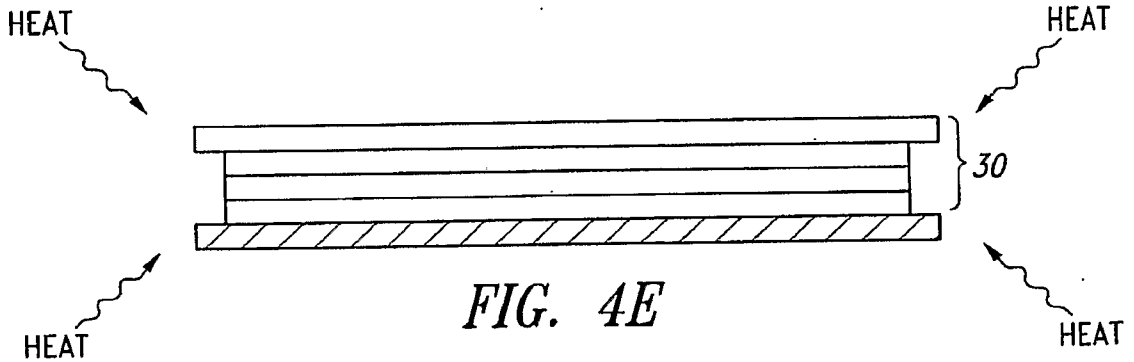


FIG. 4E