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(54) Title: FUEL CELL SEALING ARRANGEMENT, AND ASSEMBLY OF FUEL CELL STACK

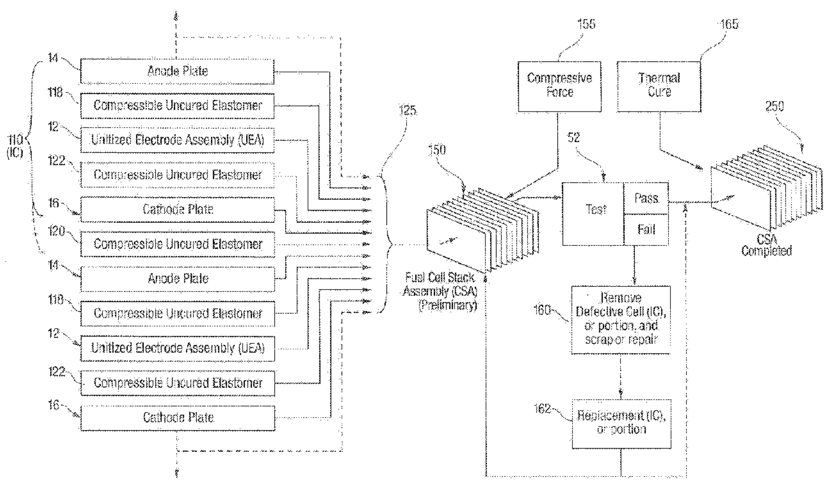

Fig.4

(57) Abstract: In the formation of a fuel cell stack assembly (CSA) (150, 250) comprised of a repeating sequence of multiple individual fuel cells (IC's) (110) each having a unified electrode assembly (UEA)(12), an anode plate (14), and a cathode plate (16), uncured elastomer seal material (118, 122, 120) is interposed between adjacent pairs of the UEA, the anode plate, and the cathode plate throughout the CSA. A compressive force (155) applied to the CSA causes the uncured elastomer seal material to flow and create temporary seals. The thus temporarily-sealed preliminary CSA (150) is then tested (52) for defects, and any defective IC's or component portions thereof are easily removed (160) and replaced (162). The CSA (150), and particularly the temporary seals thereof, is/are then thermally cured (165), typically at a low temperature, to provide a permanently-sealed CSA (250).

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FUEL CELL SEALING ARRANGEMENT, AND ASSEMBLY OF FUEL CELL STACK

BACKGROUND

Technical Field

[0001] The disclosure relates generally to fuel cells, and more particularly to fuel cell sealing arrangements and methods employing fuel cell sealing arrangements for the fabrication and assembly of fuel cell stacks.

Description of the Related Art

[0002] Fuel cells, for example Proton Exchange Membrane (PEM) fuel cells, are well known and are typically arranged and grouped collectively as a fuel cell stack assembly (CSA). Each individual fuel cell (IC) in a CSA may typically include a membrane electrode assembly (MEA) combined with gas diffusion layers (GDL's) to form a unitized electrode assembly (UEA), an anode plate, and a cathode plate, collectively assembled to form the respective fuel cell. The MEA includes an electrolyte in the form of a central proton exchange membrane (PEM), with anode and cathode catalyst layers on opposite sides of the membrane electrolyte. Gas diffusion layers (GDL's) may be positioned adjacent the outer surfaces of the MEA's catalyst layers and joined with the MEA in sealed, unitized form to create the UEA. The fuel cells utilize fuel and oxidant reactants, such as hydrogen and air, respectively, supplied via respective associated manifolds, to generate electrical energy in a known manner. The fuel cells may also generate liquid and thermal byproducts.

[0003] The anode plate and the cathode plate may be variously known or referred to as bipolar plates, separator plates, field flow plates, or the like. In one type of fuel cell, the anode plate and the cathode plate may be referred to as water transfer plates (WTP's), or more specifically as a fuel WTP and an air WTP, for the delivery of reactants to the UEA and the further conveyance of water in and from the fuel cell.

[0004] The collective components of a fuel cell, e.g., the UEA, the anode plate and the cathode plate have in some instances been assembled, bonded, and handled as a unit termed a unitized cell assembly (UCA) for subsequent assembly into the CSA. Because of a need for isolating and confining the flows of various fluids such as fuel, oxidant and coolant/water, there is a need to seal each component of the fuel cell or UCA. Moreover, there is need to seal each fuel cell or UCA from the next in the CSA. Accordingly, various arrangements of sealing and bonding have been used in the formation of the fuel cells and their assembly into the CSA.

[0005] Referring to Fig. **1**, there is depicted, in exploded form, an example of a fuel cell, specifically a UCA, 10 and its associated bonding and sealing materials. The UCA 10 includes a unitized electrode assembly (UEA) 12, an anode plate 14 and a cathode plate 16. The UEA 12 typically includes a central PEM electrolyte, and anode and cathode catalyst layers on opposite sides thereof (not shown), as well as GDL's (not shown) adjacent the respective anode and cathode catalyst layers. These elements are preassembled and sealed to form the unified structure that is the UEA 12. In the example, the anode plate 14 is a fuel WTP and the cathode plate 16 is an air WTP and although they could be depicted as being adjacent opposite sides or surfaces of the UEA 12, they are depicted as both being to one side of the UEA for beneficial mated relation with one another to create the sealed arrangement of a UCA 10. It will be appreciated that juxtaposing UCA10's in sequence creates the appropriate positional relationship between a cathode plate 16 of one UCA and the cathode side of the UEA 12 of the next succeeding UCA, and it is only necessary to modify the structure of the UCA at each end of the resulting CSA.

[0006] Each UCA 10 includes internal sealing and must also be sealed from the next UCA in the resulting CSA. Referring further to Fig. **1** and additionally to the process depicted in Fig. **2,** the formation of a sealed UCA 10 has involved locating a fuel bond film 18 between the UEA 12 and the anode plate 14, a coolant bond film 20 between the anode plate 14 and the cathode plate 16, and mutually bonding those components. The fuel bond film 18 and the coolant bond film 20 may typically be low density polyethylene (LDPE), and the mutual bonding of the components involves a heat pressing process 30 that is labor intensive and requires a high cycle time. The UCA 10 is removed from its bonding fixture, and an interfacial seal 22 is then, or subsequently, manually applied to an appropriate end of the UCA for sealing engagement with the next-adjacent UCA in the CSA. Following fabrication of the individual sealed UCA's 10 and application of respective interfacial seals 22, a number of those UCA's 10 are assembled into a CSA 50. The CSA 50 is then tested at least for pressure, as represented by block 52. Any UCA 10 which fails the test is separately identified, and then is removed from the CSA 50 and scrapped, as represented by block 60, because it exists as a bonded unit. The consequence of failed UCA's 10 is not only the loss of the assembly time involved, but also the associated cost of expensive materials, such as catalysts, which are necessarily part of the bonded unit. Any defective UCA 10 removed from CSA 50 is replaced at block 62 with a "new" replacement UCA 10.

SUMMARY

[0007] Individual fuel cells (IC's) comprise a unitized electrode assembly (UEA), an anode plate and a cathode plate arranged in a juxtaposed functional sequence, and include uncured, elastomer seals positioned in sealing relation between at least one, and typically each, of the adjacent members of the sequence. An interfacial seal of the same or similar uncured elastomer seal material is typically included at an end face of the IC to provide a seal with the next-adjacent IC. These elastomer seals are of a material that, before curing, exhibits a resilient flowability under compression and, after curing at a relatively low temperature, provides a permanent seal between the adjacent members. Example elastomer seal materials may be non-silicone and may include ethylene propylene diene monomer (EPDM) rubber, fluoroelastomer materials (as for example represented by Dyneon™ FKM material manufactured by 3M Company), and the like.

[0008] The IC's are assembled into a fuel cell stack assembly (CSA) employing a method that advantageously uses the properties of the elastomer seal material(s). The UEA, the anode plate, and the cathode plate are assembled in a juxtaposed functional sequence to form an IC, with the elastomer seal material in an uncured state interposed in appropriate regions between paired members, or components, of the sequence. The formation or assembly of the CSA may be by successive individual components of the IC's or by preassembled IC's. Although the anode plate and cathode plate of an IC may be depicted as both being to the same side of the UEA, as in Fig. 1, it is perhaps more appropriate and conventional to consider them as being on opposite sides of the UEA. As noted above, an interfacial seal of the same or similar uncured elastomer seal material is applied to an end face of the IC, and the process is repeated to accumulate successive IC's into a CSA. A compressive force is applied to the CSA during stack loading and/or assembly, which causes the uncured seals to compress and flow and thereby preliminarily or temporarily seal the CSA. The preliminarily-sealed CSA is then pressure tested, and any defective IC's, or portions thereof, are identified and relatively easily removed from the stack. A defective IC may be removed in its entirety or only the defective portion, and an acceptable IC or portion is inserted as a replacement. The removed IC, or portion, may be salvaged, as for example by repair for reuse. Following completion of assembly, the CSA is put through a low-temperature cure cycle by any of several methods to cause the uncured elastomer seal material to flow, cure, and form a permanent seal. The low temperature cure cycle may be in the range of about 70^0 C to less than about 150^0 C, with an example being in the range of about 70^0 C to less than 100^0 C.

[0009] Other systems, methods, features and/or advantages of this disclosure will be or may become apparent to one with skill in the art upon examination of the following drawings and detailed description. It is intended that all such additional systems, methods, features and/or advantages be included within this description and be within the scope of the present disclosure.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010]] Many aspects of the disclosure can be better understood with reference to the following drawings. The components in the drawings are not necessarily to scale. Moreover, in the drawings, like reference numerals designate corresponding parts throughout the several views.

[0011] Fig. **1** is an exploded view of a prior art unitized fuel cell assembly.

[0012] Fig. **2** is a simplified diagram illustrating the process of producing a fuel cell stack assembly using unitized cell assemblies as depicted in **Fig. 1.**

[0013] Fig. **3** is an exploded view of the several components of an individual fuel cell depicting uncured elastomer seals in accordance with an embodiment of the present disclosure.

[0014] Fig. **4** is a simplified diagram illustrating a process in accordance with an embodiment of the present disclosure of producing a fuel cell stack assembly using the components of the individual fuel cells depicted in Fig. **3**.

DETAILED DESCRIPTION

[0015] Referring first to Fig. **3** , there is depicted, in exploded form, an individual fuel cell (IC) 110 in accordance with an embodiment of the present disclosure. This IC 110 is similar in many respects to the UCA 10 of Fig. **1**, including the use of a unitized electrode assembly (UEA) 12, an anode plate 14 and a cathode plate 16. The UEA 12 typically includes a central PEM electrolyte, and anode and cathode catalyst layers on opposite sides thereof (not shown), as well as GDL's (not shown) adjacent the respective anode and cathode catalyst layers. These elements are preassembled and sealed to form the unified structure that is the UEA 12. In the example, the anode plate 14 is a fuel WTP and the cathode plate 16 is an air WTP. The components of the IC 110 are here depicted in a somewhat more conventional manner than for the UCA 10 of Fig. **1**, with the anode plate 14 being to one side of the UEA 12 and the cathode plate 16 being to the opposite side, though it will be appreciated that both depictions are functionally equivalent when assembled into a stack containing many fuel cells.

[0016] The IC 110 of Fig. **3** differs, however, from the UCA 10 of Fig. **1** in several ways. A seal 118 between the UEA 12 and the anode plate 14, a seal 122 between the UEA 12 and the cathode plate 16, and an interfacial seal 120 at an end of the IC 110, as adjacent the cathode plate 16, are all of a material, or materials, that differ from the materials of previously mentioned fuel bond film 18, coolant bond film 20, and interfacial seal 22, and they are uncured. Moreover, as will become clear, the IC 110, and particularly the UEA 12, anode plate 14, and cathode plate 16, will remain in a non-bonded or "un-unified" state during much of the stack assembly process which follows. While the discussion of the Fig. **1** UCA 10 tended to treat the interfacial seal 22 as separate from the UCA until assembly of the stack, it is convenient and appropriate, though not essential, herein to treat the interfacial seal 120 as an included portion or component of the IC 110.

[0017] The seals 118, 120 and 122 are of an elastomer material that, before curing, exhibits a resilient flowability under compression and, after curing at a relatively low temperature, provides a permanent seal between the adjacent members. In an example material, a non-silicone elastomer may be used to advantage. Examples of suitable non-silicone elastomer seal materials include ethylene propylene diene monomer (EPDM) rubber, fluoroelastomer materials (as for example represented by Dyneon™ FKM material manufactured by 3M Company), and the like. The material of seals 118, 120, and 122 remains uncured at normal assembly temperatures, typically between about 25^0 - 60^0 C, and below, but may cure at temperatures as low as about 70^0 - 80^0 C and above. Moreover, the seals 118, 120, and 122 may be applied to and/or between the appropriate elements/components of the IC 110 in any of various forms, including extrusion, preformed strips, completed preformed shapes, and the like. In the illustrated embodiment, the seals 122, 118, and 120 respectively are either preformed shapes and/or are strips from a roll; and are applied, uncured, to seats or notches 13, 15, and 17 in, or on, the UEA 12, the anode plate 14, and the cathode plate 16, respectively. The notches or seats 13, 15, and 17 are generally positioned about some, most, or all, of the periphery of each of the elements on which they reside. Notably, the notches or seats 15 and 17, and thus their accompanying seals 118 and 120, are discontinued in regions where flows of respective fluids, eg, of fuel and oxidant, are intended to enter or exit flow paths provided between adjacent members of an IC 110, as from or to appropriate manifolds. The above mentioned material of seals 118, 120, and 122 adheres well to the graphite of which at least the anode plate 14 and cathode plate 16 of the example embodiment are made.

[0018] Referring also to Fig. 4, there is depicted an example process for the manufacture and assembly of the component portions of typically multiple IC's 110 to a completed fuel cell stack assembly (CSA) 250. As noted earlier, an IC 110 includes at least the principal components of UEA 12, anode plate 14, and cathode plate 16, and, at this stage, compressible, uncured elastomer material for seals 118, 120 and 122 interposed between those principal components and adjacent the third, depending upon the sequence of the principal components chosen to define an IC 110. The chosen sequence is repeated a number of times at a preliminary assembly station 125 to create, or load, a preliminary fuel cell stack assembly (CSA) 150 containing multiple IC's 110. It will be appreciated that the assembly occurring at station 125 may be accomplished using successive component-by-component assembly of successive IC 110's at that station, or it may be accomplished using IC's 110 preassembled prior to that station, with the same result.

[0019] A compressive force 155 is applied axially, or longitudinally, to the preliminary CSA 150, as by pressure plates of known design, to cause the uncured seals 118, 120, and 122 to compress and flow, thereby temporarily sealing the FCA's 110 and thus also the preliminary CSA 150 at this stage. That compressive force may typically be in the range of 0.31 to 0.69 MPa (45 to 100 psi). The quality of the seals and sealing which results is sufficient to allow pressure testing of the CSA 150 and its included components at this time.

[0020] The preliminary CSA 150 is pressure tested at block 52 at a pressure in the range of about 0.01 to 0.055 MPa (1.5 to 9.0 psi). Although this is lower than the approximately 0.06 to 0.08 MPa pressures (9.5 to 12 psi) at which the stack will ultimately operate, it is generally sufficient to determine the integrity of the components, including seals, in the stack assembly. It is presumed that the preliminary CSA 150 will, in the main, pass the pressure test at block 52, however it is also possible that one or more components associated with one or more of the IC's 110 may fail. Such failure in an IC 110 may include pinhole leaks, or the like, in one or more of the UEA 12, the anode plate 14, the cathode plate, and the seals 118, 120, and 122. In the event such a failure is detected, either all, or at least the relevant component or portion, of the "failed" IC 110 is removed at 160 from the CSA 150 and either scrapped, or preferably repaired and reused. The fact that the individual component portions of the IC 110 have not yet been bonded into a unitized cell assembly permits easy access to those components individually, for either repair or for scrapping. Because of the costs, as for instance of the UEA 12 with its associated catalysts, it may be important to easily recover and/or reuse the non-failed or the repaired, component portions of the FCA 110 that failed the pressure test 52.

[0021] In any event, for each IC 110, or component portion thereof, that is removed from the preliminary CSA 150 because it failed the test 52, it is necessary to replace that removed portion, as represented by function block 160. The replacement may be a new IC 110 or a component portion such as a plate, UEA, and/or a seal, or it may be a repair and reuse of a "failed" IC or component portion. The replacement function 162 is depicted in solid line as entering the process stream prior to the testing function 40 for inclusion with the "passed" portion of the preliminary CSA 150 to undergo a further, or follow-on, pressure test following the replacement. An alternative to the foregoing is depicted in broken line, showing the replacement function 162 entering the process stream after the test block 52, but would be used only if there is a certainty that the replacement component is not defective.

[0022] Following pressure testing of the preliminary CSA 150, and acceptable replacement of any defective IC's 110 or component portions thereof, the CSA is completed at 250 upon undergoing a low temperature thermal cure cycle 165 while maintaining the loading previously indicated by compressive force 155. The thermal cure 165 causes the uncured elastomers of seals 118, 120, and 122 to flow and cure and form a permanent seal. The thermal cure cycle 165 may be provided by any of several methods, including subjecting the entire CSA to a cure cycle in a low temperature oven, or by flowing heated water through the flow fields that exist within the respective IC's110 of the CSA, or by actually operating the CSA at a low thermal level. This cure is easily attained by maintaining the temperatures in the CSA 250 above about 70^0 to 80^0 C for an appropriate interval. Indeed, cure temperatures near or somewhat above 80^0 C do no harm to any of the components of the CSA 250, so long as they remain below the maximum allowable temperature for the MEA in UEA

12, which may be as much as 150^0 C. In an example embodiment, the cure temperature is in a range of about 70^0 C to less than about 100^0 C.

[0023] It should be emphasized that the above-described embodiment(s) are merely possible examples of implementations set forth for a clear understanding of the principles of this disclosure. Many variations and modifications may be made to the above-described embodiments without departing substantially from the spirit and principles of the disclosure. For instance, although the example embodiment of the IC's and CSA of the present disclosure is presented as having external manifolds, the disclosed method of assembly would apply equally to IC's and CSA's having internal manifolds. Similarly, the disclosed method of assembly is equally applicable to either the cumulative layup of individual components to form the ultimate CSA, or to the prior layup of components to form IC's and then the layup of those IC's to form the ultimate CSA, so long as the seals between the major components remained uncured until after the testing. All such modifications and variations are intended to be included herein within the scope of this disclosure and protected by the accompanying claims.

CLAIMS

What is claimed is:

1. A preliminary fuel cell stack assembly (CSA)(150), comprising:

multiple individual fuel cells (IC's)(110) arranged in repeating sequence, each IC comprising at least a unified electrode assembly (UEA)(12), an anode plate (14), and a cathode plate (16) collectively arranged in pairs that provide an operative sequence throughout the CSA, and

a respective compressible, uncured elastomer seal (118, 122, 120) between at least one of said adjacent pairs of said UEA, said anode plate, and said cathode plate, and between adjacent IC's, throughout said repeating sequence in said CSA.

2. The preliminary fuel cell stack assembly (CSA) of claim **1** wherein a respective said compressible, uncured elastomer seal (118, 122, 120) is positioned between each of said adjacent pairs of said UEA, said anode plate, and said cathode plate, and between adjacent IC's, throughout said repeating sequence in said CSA.

3 The preliminary fuel cell stack assembly (CSA) of claim **1** wherein the elastomer seals are of a material which remains uncured for temperatures in the range of about 45^0 to 60^0 C and which cure at temperatures in the range of about 70^0 to less than 150^0 C..

4. The preliminary fuel cell stack assembly (CSA) of claim **3** wherein said elastomer seals comprise a flouroelastomer.

5 The preliminary fuel cell stack assembly (CSA) of claim 3 wherein said elastomer seals comprise an ethylene propylene diene monomer (EPDM) rubber.

6. The preliminary fuel cell stack assembly (CSA) of claim 3 wherein said elastomer seals are of a non-silicone material.

7. The preliminary fuel cell stack assembly (CSA) of claim 2 wherein said CSA is under a compressive load (155) to thereby effect temporary sealing by said uncured elastomer seals between the respective adjacent said pairs of said UEA, said anode plate, said cathode plate, and adjacent IC's.

8. A method of manufacturing a fuel cell stack assembly (CSA) (250) including multiple individual fuel cells (IC's)(110) in a repeating sequence, each IC including at least a unified electrode assembly (UEA)(12), an anode plate (14), and a cathode plate (16) in paired relation, comprising the steps of:

interposing uncured elastomer seals (118, 122, 120) between adjacent pairs of at least one of said UEA, said anode plate, and said cathode plate throughout the CSA;

applying a compressive force (155) to the CSA to establish temporary seals between said adjacent pairs of said UEA, said anode plate, and said cathode plate throughout the CSA;

testing (52) the CSA while temporarily sealed to identify defective IC's or portions thereof;

replacing (162, 160) the identified defective IC's or portions thereof ; and

thermally curing (165) said temporary seals to provide permanent seals.

9. The method of claim **8** comprising interposing said uncured elastomer seals (118, 122, 120) between each adjacent pair of said UEA, said anode plate, and said cathode plate throughout the CSA.

10. The method of claim **8** wherein said step of replacing (162, 160) the identified defective IC's or portions thereof comprises the steps of:

removing (160) identified defective IC's or portions thereof from the CSA; and

replacing (162) the removed IC's or portions thereof with respective new or repaired IC's or portions thereof.

11. The method of claim **8** wherein the step of testing the CSA comprises pressure testing said CSA and included IC's and portions thereof.

12. The method of claim **11** wherein said pressure testing is at a pressure in a range of about 0.01 to 0.055 MPa.

13. The method of claim **8** wherein said step of thermally curing said seals compris exposing said seals to a cure temperature in a range of about 70^0 to less than about 150^0 C for a cure interval.

14. The method of claim **13** wherein said step of exposing said seals to said cure temperature comprises heating in a low temperature oven.

15. The method of claim **13** wherein said step of exposing said seals to said cure temperature comprises flowing heated water through said CSA.

16. The method of claim **13** wherein said step of exposing said seals to said cure temperature comprises operating said CSA at a low thermal level.

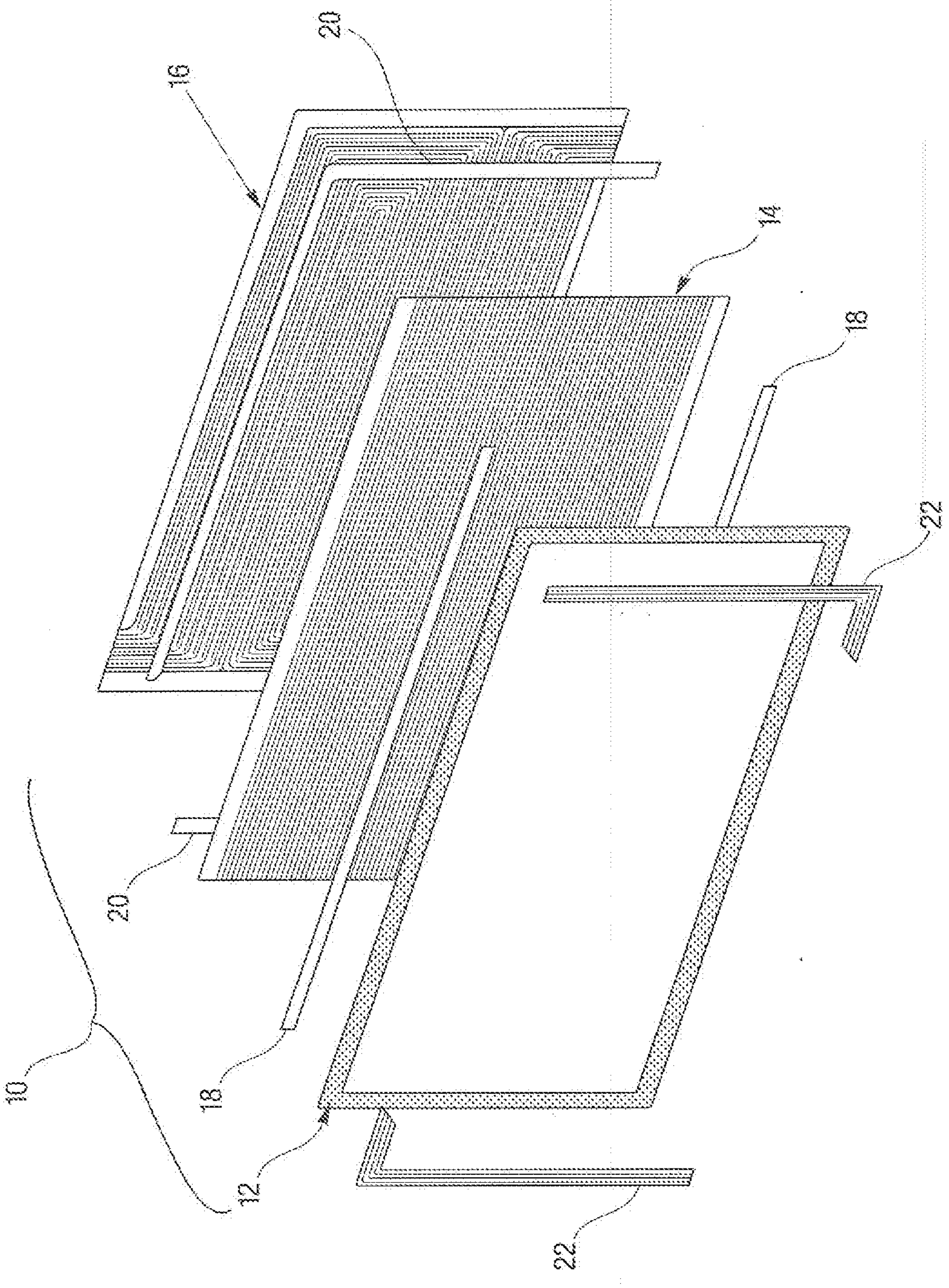

Fig. 1
Prior Art

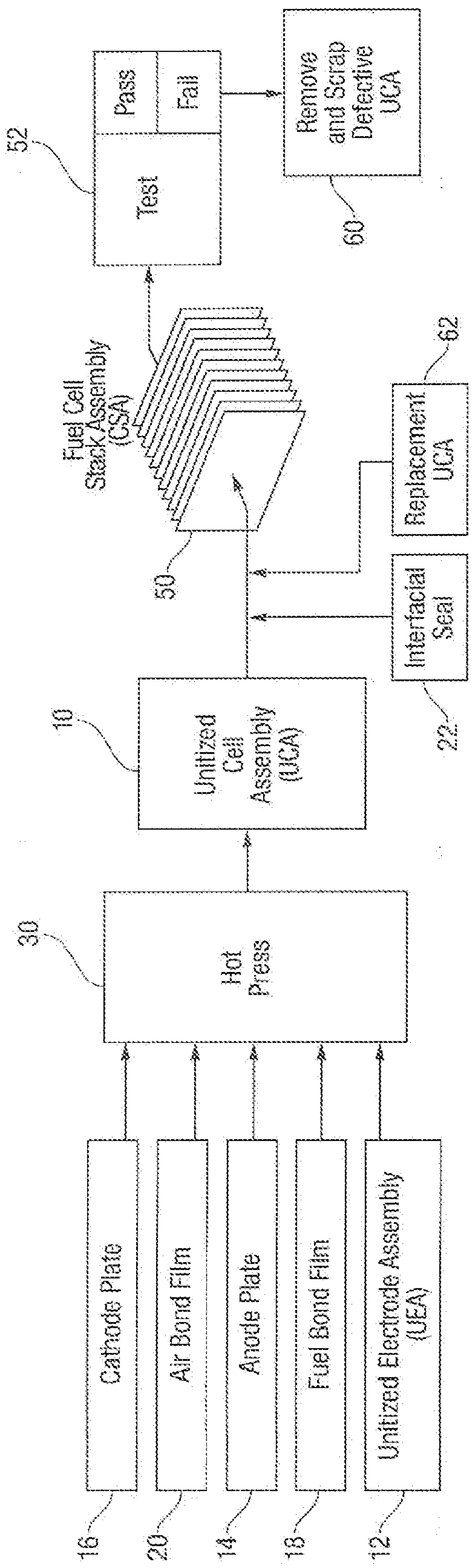

Fig.2
Prior Art

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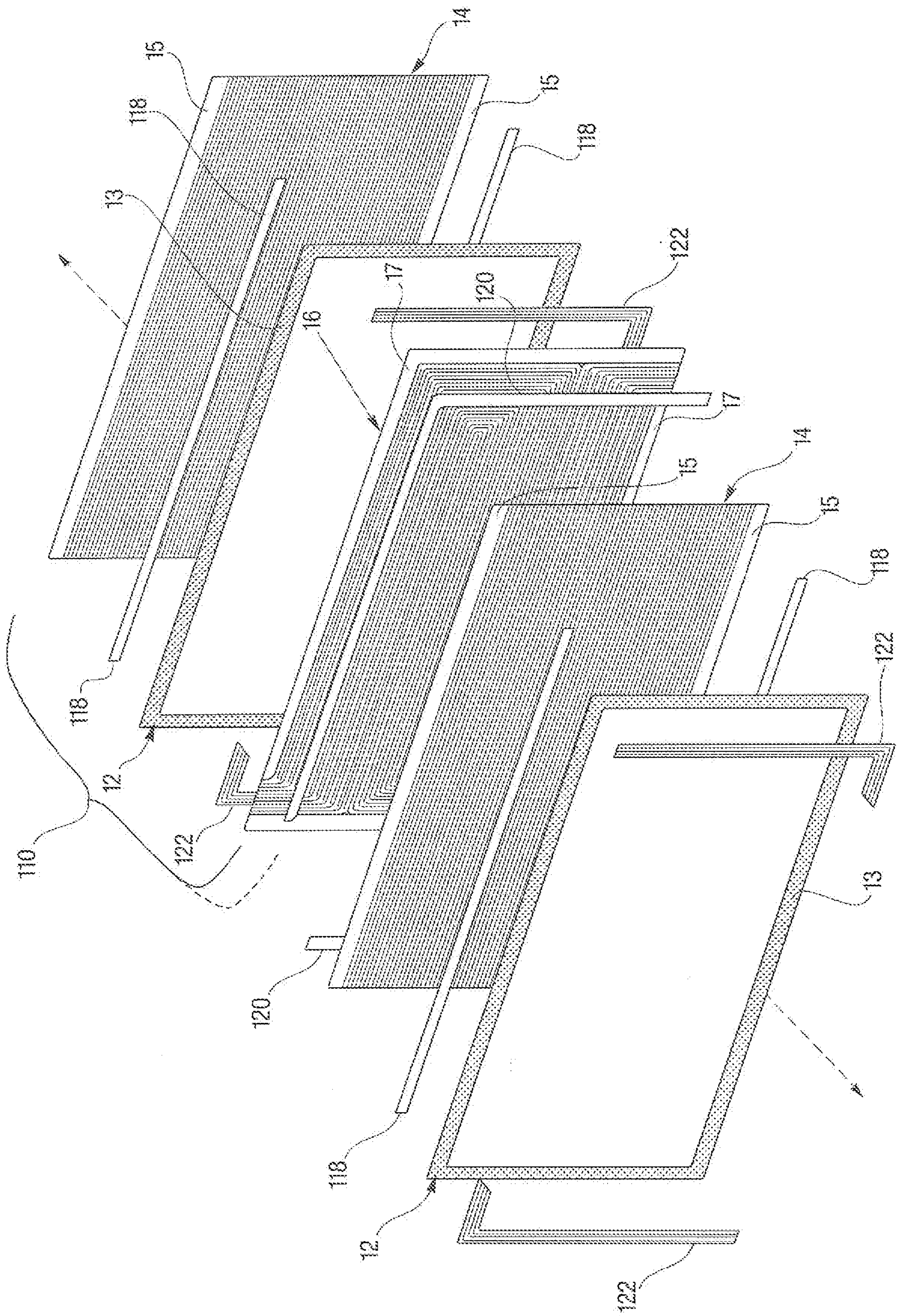

Fig. 3

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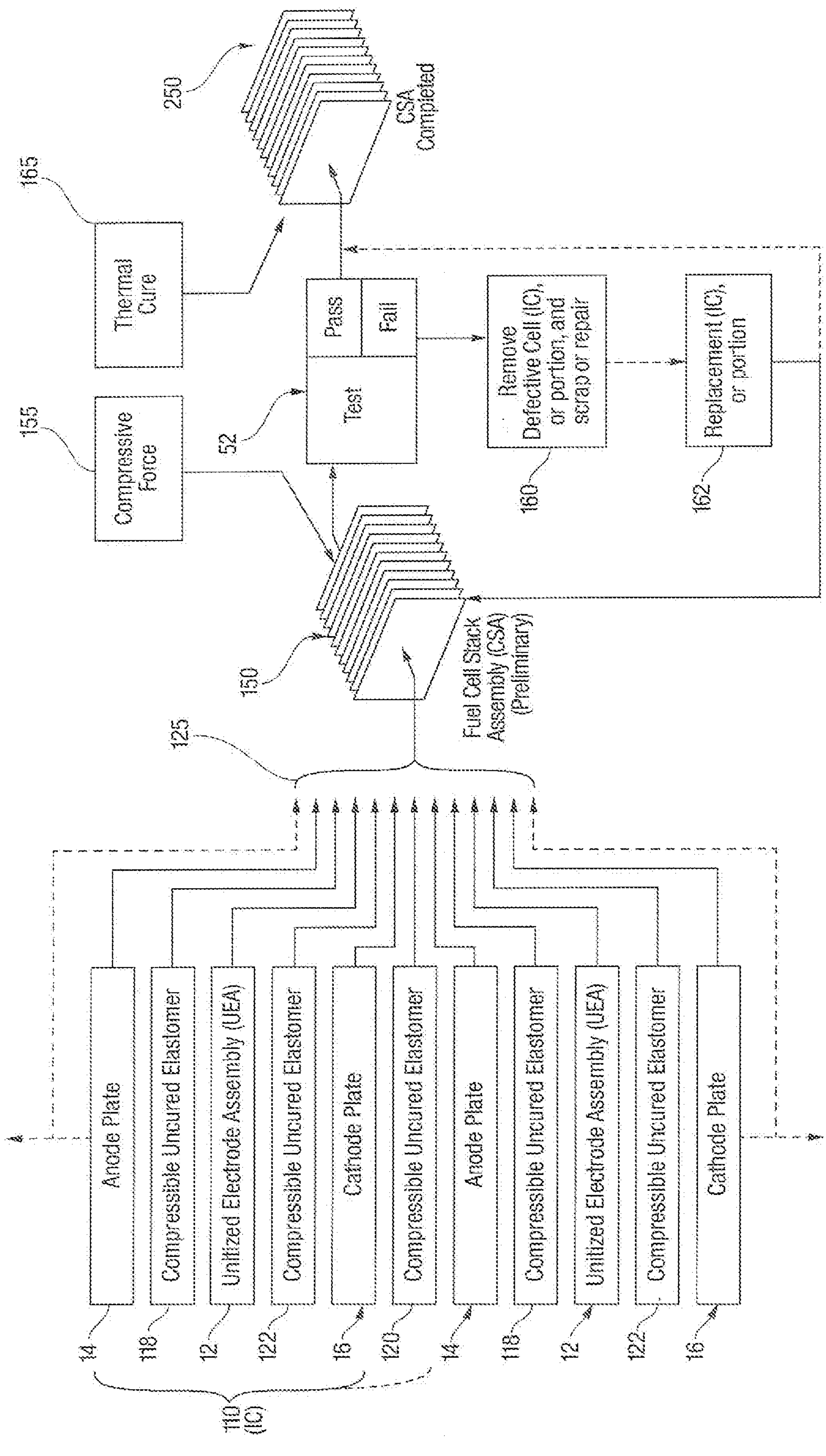
Anode Plate
Compressible Uncured Elastomer
Unitized Electrode Assembly (UEA)
Compressible Uncured Elastomer
Cathode Plate
Compressible Uncured Elastomer
Anode Plate
Compressible Uncured Elastomer
Unitized Electrode Assembly (UEA)
Compressible Uncured Elastomer
Cathode Plate
14
118
12
122
16
120
14
118
12
122
16
110
(IC)
125
150
Fuel Cell Stack Assembly (CSA) (Preliminary)
155
Compressive Force
52
Test
Pass
Fail
165
Thermal Cure
250
CSA Completed
160
Remove Defective Cell (IC), or portion, and scrap or repair
162
Replacement (IC), or portion

Fig. 4

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2012/046028

A. CLASSIFICATION OF SUBJECT MATTER

H01M 8/24(2006.01)i, H01M 8/02(2006.01)i, H01M 8/10(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H01M 8/24; H01M 8/02; H01M 8/10; H01M 8/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords:fuel cell, sealing arrangement, uncured elastomer, cell stack assembly

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2011-0305976 A1 (TANAHASHI HIDEAKI et al.) 15 December 2011 See the abstract, paragraph [15], [20], [36], [58]-[81], [87], claim 1 and fig. 4-11	1-10,13,14,16
A	See the abstract, paragraph [15], [20], [36], [58]-[81], [87], claim 1 and fig. 4-11	11,12,15
Y	JP 2009-009912 A (NISSAN MOTOR CO LTD) 15 January 2009 See the abstract, paragraph [17], [36]-[39], [60]-[64], claim 1-2, 10, 14-16 and fig.3-10	1-3,5-10,13,14,16
A	See the abstract, paragraph [17], [36]-[39], [60]-[64], claim 1-2, 10, 14-16 and fig.3-10	4,11,12,15
Y	US 2004-0229106 A1 (YASUMOTO EIICHI et al.) 18 November 2004 See the abstract, paragraph [44]-[46], [55], [56], claim 11-16 and fig. 1-13	4
A	See the abstract, paragraph [44]-[46], [55], [56], claim 11-16 and fig. 1-13	1-3,5-16

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

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Information on patent family members

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