CLAIMS

1. A hydrogen gas purifier cell comprising:

a first membrane electrode assembly (MEA) comprising:

a first anode positioned to contact a first gas stream having a first hydrogen gas content and a first impurity gas content, the first anode containing a catalyst adapted to oxidize at least some of first hydrogen gas content to produce hydrogen ions and electrons;

a first electrolyte positioned and adapted to receive and transfer at least some of the hydrogen ions produced by the first anode; and

a first cathode positioned to receive at least some of the hydrogen ions transferred by the first electrolyte, the first cathode containing a catalyst adapted to reduce the at least some of the hydrogen ions to produce a second gas stream having a second hydrogen gas content greater than the first hydrogen gas content and a second impurity gas content less than the first impurity gas content;

a second MEA comprising:

a second anode positioned adjacent the first cathode to receive the second gas stream from the first cathode of the first MEA, the second anode containing a catalyst adapted to oxidize at least some of second hydrogen gas content in the second gas stream to produce hydrogen ions and electrons;

a second electrolyte positioned and adapted to receive and transfer at least some of the hydrogen ions produced by the second anode; and

a second cathode positioned to receive at least some of the hydrogen ions transferred by the second electrolyte of the second MEA, the second cathode containing a catalyst adapted to reduce the at least

some of the hydrogen ions to produce a third gas stream having a third hydrogen gas content greater than the first hydrogen gas content and a third impurity gas content less than the first impurity gas content.

2. The hydrogen gas purifier cell as recited in claim 1, wherein the purifier cell further comprises at least one passage between the first electrolyte and the second electrolyte for discharging at least some of the second gas stream.

3. The hydrogen gas purifier cell as recited in claim 2, wherein the at least one passage is located between the first cathode and the second anode.

4. The hydrogen gas purifier cell as recited in claim 3, wherein the at least one passage located between the first cathode and the second anode comprises voids between mating surfaces of the first cathode and the second anode.

5. The hydrogen gas purifier cell as recited in claim 3, wherein the purifier cell further comprises a gas-permeable layer (GDL) between the first cathode and the second anode, and wherein the GDL provides the at least one passage located between the first cathode and the second anode.

6. The hydrogen gas purifier cell as recited in claim 5, wherein the GDL comprises a carbon-based, gas-permeable layer.

7. The hydrogen gas purifier cell as recited in any one of claims 2 to 6, wherein the at least one passage comprises at least one channel in close proximity to at least one of the first cathode and the second anode.

8. The hydrogen gas purifier cell as recited in any one of claims 1 to 7, wherein the purifier cell further comprises at least one passage between the first electrolyte and the second electrolyte for introducing hydrogen-containing gas to the second gas stream.

9. The hydrogen gas purifier cell as recited in claim 8, wherein the at least one passage is located between the first cathode and the second anode.

10. The hydrogen gas purifier cell as recited in claim 9, wherein the at least one passage located between the first cathode and the second anode comprises voids between mating surfaces of the first cathode and the second anode.

11. The hydrogen gas purifier cell as recited in claim 1, wherein the second gas stream passes directly from the first cathode to the second anode.

12. The hydrogen gas purifier cell as recited in claim 11, wherein the second gas stream passes directly from the first cathode to the second anode without passing out of the hydrogen gas purifier cell.

13. The hydrogen gas purifier cell as recited in claim 1, wherein the spacing between the second anode and the first cathode is minimal.

14. The hydrogen gas purifier cell as recited in claim 1, wherein the spacing between the second anode and the first cathode is 0.1 mm to 0.5 mm.

15. The hydrogen gas purifier cell as recited in claim 1, wherein the second anode contacts the first cathode.

16. The hydrogen gas purifier cell as recited in claim 1, wherein the second gas stream passes from the first cathode to the second anode without any intervening handling.

17. A hydrogen gas purifier cell comprising:

a first membrane electrode assembly (MEA) comprising:

a first anode positioned to contact a first gas stream having a first hydrogen gas content and a first impurity gas content, the first anode containing a catalyst adapted to oxidize at least some of first hydrogen gas content to produce hydrogen ions and electrons;

a first electrolyte positioned and adapted to receive and transfer at least some of the hydrogen ions produced by the first anode; and

a first cathode positioned to receive at least some of the hydrogen ions transferred by the first electrolyte, the first cathode containing a catalyst adapted to reduce the at least some of the hydrogen ions to produce a second gas stream having a second hydrogen gas content greater than the first hydrogen gas content and a second impurity gas content less than the first impurity gas content;

a second MEA comprising:

a second anode positioned to receive the second gas stream from the first cathode of the first MEA, the second anode containing a catalyst adapted to oxidize at least some of second hydrogen gas content in the second gas stream to produce hydrogen ions and electrons;

a second electrolyte positioned and adapted to receive and transfer at least some of the hydrogen ions produced by the second anode; and

a second cathode positioned to receive at least some of the hydrogen ions transferred by the second electrolyte of the second MEA, the second cathode containing a catalyst adapted to reduce the at least some of the hydrogen ions to produce a third gas stream having a third hydrogen gas content greater than the first hydrogen gas content and a third impurity gas content less than the first impurity gas content; and

at least one passage between the first electrolyte and the second electrolyte for discharging at least some of the second gas stream, the at least one passage comprising voids between mating surfaces of the first cathode and the second anode.

18. The hydrogen gas purifier cell as recited in claim 11, wherein the purifier cell further comprises at least one passage between the first electrolyte and the second electrolyte for introducing the hydrogen-containing gas to the second gas stream.

19. The hydrogen gas purifier cell as recited in claim 18, wherein the at least one passage between the first electrolyte and the second electrolyte for introducing hydrogen-containing gas to the second gas stream comprises the voids between the mating surfaces of the first cathode and the second anode.

20. A hydrogen gas purifier cell comprising:

a first membrane electrode assembly (MEA) comprising:

a first anode positioned to contact a first gas stream having a first hydrogen gas content and a first impurity gas content, the first anode containing a catalyst adapted to oxidize at least some of first hydrogen gas content to produce hydrogen ions and electrons;

a first electrolyte positioned and adapted to receive and transfer at least some of the hydrogen ions produced by the first anode; and

a first cathode positioned to receive at least some of the hydrogen ions transferred by the first electrolyte, the first cathode containing a catalyst adapted to reduce the at least some of the hydrogen ions to produce a second gas stream having a second hydrogen gas content greater than the first hydrogen gas content and a second impurity gas content less than the first impurity gas content;

a second MEA comprising:

a second anode positioned to receive the second gas stream from the first cathode of the first MEA, the second anode containing a catalyst adapted to oxidize at least some of second hydrogen gas content in the second gas stream to produce hydrogen ions and electrons;

a second electrolyte positioned and adapted to receive and transfer at least some of the hydrogen ions produced by the second anode; and

a second cathode positioned to receive at least some of the hydrogen ions transferred by the second electrolyte of the second MEA, the second cathode containing a catalyst adapted to reduce the at least some of the hydrogen ions to produce a third gas stream having a third hydrogen gas content greater than the first hydrogen gas content and a third impurity gas content less than the first impurity gas content; and

at least one passage between the first electrolyte and the second electrolyte for introducing hydrogen-containing gas to the second gas stream, the at least one passage comprising voids between mating surfaces of the first cathode and the second anode.

21. The hydrogen gas purifier cell as recited in claim 20, wherein the purifier cell further comprises at least one passage between the first electrolyte and the second electrolyte for discharging at least some of the second gas stream.

22. The hydrogen gas purifier cell as recited in claim 21, wherein the at least one passage between the first electrolyte and the second electrolyte for discharging at least some of the second gas stream comprises the voids between the mating surfaces of the first cathode and the second anode.

23. A hydrogen gas purifier cell comprising:

a membrane electrode assembly (MEA) comprising:

an anode positioned to contact a first gas stream having a first hydrogen gas content and a first impurity gas content, the anode containing a catalyst adapted to oxidize at least some of first hydrogen gas content to produce hydrogen ions and electrons;

a first electrolyte positioned and adapted to receive and transfer at least some of the hydrogen ions received from the anode;

a dual electrode positioned to receive at least some of the hydrogen ions transferred by the first electrolyte, the dual cathode containing a catalyst adapted

to reduce the at least some of the hydrogen ions to produce a second gas stream having a second hydrogen gas content and to oxidize at least some of second hydrogen gas content in the second gas stream to produce hydrogen ions and electrons;

a second electrolyte positioned and adapted to receive and transfer at least some of the hydrogen ions received from the dual electrode; and

a cathode positioned to receive at least some of the hydrogen ions transferred by the second electrolyte, the cathode containing a catalyst adapted to reduce the at least some of the hydrogen ions and electrons to produce a third gas stream having a third hydrogen gas content greater than the first hydrogen gas content and a third impurity gas content less than the first impurity gas content.

24. The hydrogen gas purifier cell as recited in claim 23, wherein the cell further comprises at least one passage for removing at least some of the second gas stream.

25. The hydrogen gas purifier cell as recited in claim 24, wherein the at least one passage comprises the dual electrode.

26. The hydrogen gas purifier cell as recited in claim 25, wherein the at least one passage comprises permeability of the dual electrode.

27. The hydrogen gas purifier cell as recited in any one of claims 24 to 26, wherein the at least one passage comprises a gas permeable diffusion layer.

28. The hydrogen gas purifier cell as recited in any one of claims 24 to 27, wherein the at least one passage comprises the second electrolyte.

29. The hydrogen gas purifier cell as recited in any one of claims 23 to 28, wherein the cell further comprises at least one passage for introducing at least some hydrogen gas to the second gas stream.

30. The hydrogen gas purifier cell as recited in claim 29, wherein the at least one passage comprises the dual electrode.

31. The hydrogen gas purifier cell as recited in any one of claims 24 to 30, wherein the at least one passage comprises a gas permeable diffusion layer.

32. The hydrogen gas purifier cell as recited in any one of claims 24 to 31, wherein the at least one passage comprises the second electrolyte.

33. A method of purifying hydrogen gas comprising:

introducing a first gas stream having a first hydrogen gas content and a first impurity gas content to an anode containing a catalyst;

in the anode, catalytically oxidizing at least some of first hydrogen gas content to produce hydrogen ions and electrons;

transferring at least some of the hydrogen ions produced in the anode through a first electrolyte to a dual electrode;

in the dual electrode, catalytically reducing the at least some of the hydrogen ions transferred through the first electrolyte to produce a second gas stream having a second hydrogen gas content, and catalytically oxidizing at least some of second hydrogen gas content in the second gas stream to produce hydrogen ions and electrons;

transferring at least some of the hydrogen ions produced in the dual electrode through a second electrolyte to a cathode, and

in the cathode, catalytically reducing the at least some of the hydrogen ions transferred through the second electrolyte to produce a third gas stream having a third hydrogen gas content greater than the first hydrogen gas content and a third impurity gas content less than the first impurity gas content.

34. The method as recited in claim 33, wherein the method further comprises removing at least some of the second gas stream.

35. The method as recited in claim 34, wherein the MEA further comprises a gas diffusion layer, and wherein removing the at least some of the second gas stream comprises removing the at least some of the second gas stream through the gas diffusion layer.

36. The method as recited in claim 33 or claim 34, wherein the dual electrode comprises a gas-permeable electrode, and wherein removing the at least some of the second gas stream comprises removing the at least some of the second gas stream through the gas-permeable dual electrode.

37. The method as recited in any one of claims 34 to 36, wherein removing the at least some of the second gas stream comprises removing the at least some of the second gas stream through the second electrolyte.

38. The method as recited in any one of claims 33 to 37, wherein the method further comprises introducing at least some hydrogen gas to the second gas stream.

39. The method as recited in claim 38, wherein the MEA further comprises a gas diffusion layer, and wherein introducing the at least some hydrogen gas to the second gas stream comprises introducing the at least some hydrogen gas to the second gas stream through the gas diffusion layer.

40. The method as recited in claim 38 or claim 39, wherein the dual electrode comprises a gas-permeable electrode, and wherein the at least some hydrogen gas to the second gas stream comprises introducing the at least some hydrogen gas to the second gas stream through the gas-permeable dual electrode.

41. The method as recited in any one of claims 38 to 40, wherein introducing the at least some hydrogen gas to the second gas stream comprises introducing the at least some hydrogen gas to the second gas stream through the second electrolyte.

42. The method as recited in any one of claims 33 to 41, wherein the third impurity gas content comprises at most at most 10 ppm of impurity gas on a dry basis.

43. A water electrolyzer cell comprising:

a first membrane electrode assembly (MEA) comprising:

a first anode positioned to contact a first H_2O-containing fluid stream, the first anode containing a catalyst adapted to oxidize at least some of the H_2O in the first H_2O-containing fluid stream to produce oxygen gas, hydrogen ions, and electrons;

a first electrolyte positioned and adapted to receive and transfer at least some of the hydrogen ions produced by the first anode ; and

a first cathode positioned to receive at least some of the hydrogen ions transferred by the first electrolyte, the first cathode containing a catalyst adapted to reduce the at least some of the hydrogen ions to produce a second fluid stream containing hydrogen gas;

a second MEA comprising:

a second anode positioned to receive the second fluid stream containing hydrogen gas from the first cathode of the first MEA, the second anode containing a catalyst adapted to oxidize at least some of the hydrogen gas to produce hydrogen ions and electrons;

a second electrolyte positioned and adapted to receive and transfer at least some of the hydrogen ions produced by the second anode; and

a second cathode positioned to receive at least some of the hydrogen ions transferred by the second electrolyte of the second MEA, the second cathode containing a catalyst adapted to reduce the at least

some of the hydrogen ions to produce a third fluid stream containing hydrogen gas.

44. The water electrolyzer cell as recited in claim 43, wherein the electrolyzer cell further comprises at least one passage between the first electrolyte and the second electrolyte for discharging at least some of the second fluid stream.

45. The water electrolyzer cell as recited in claim 44, wherein the at least one passage is located between the first cathode and the second anode.

46. The water electrolyzer purifier cell as recited in claim 45, wherein the at least one passage located between the first cathode and the second anode comprises voids between mating surfaces of the first cathode and the second anode.

47. The water electrolyzer cell as recited in claim 45 or claim 46, wherein the water electrolyzer cell further comprises a gas-permeable layer (GDL) between the first cathode and the second anode, and wherein the GDL provides the at least one passage located between the first cathode and the second anode.

48. The water electrolyzer cell as recited in any one of claims 43 to 47, wherein the water electrolyzer cell further comprises at least one passage between the first electrolyte and the second electrolyte for introducing hydrogen-containing gas to the second gas stream.

49. The water electrolyzer cell as recited in claim 48, wherein the at least one passage is located between the first cathode and the second anode.

50. The water electrolyzer cell as recited in claim 49, wherein the at least one passage located between the first cathode and the second anode comprises voids between mating surfaces of the first cathode and the second anode.

51. The water electrolyzer cell as recited in claim 49 or claim 50, wherein the water electrolyzer cell further comprises a gas-permeable layer (GDL) between

the first cathode and the second anode, and wherein the GDL provides the at least one passage located between the first cathode and the second anode.

52. The water electrolyzer cell as recited in any one of claims 43 to 51, wherein the at least one passage comprises at least one channel in a surface of at least one of the first cathode and the second anode.

53. A method for electrolyzing water, the method comprising:

introducing a first H_2O-containing fluid stream to a first anode containing a catalyst;

in the first anode, catalytically oxidizing at least some of the H_2O in the first H_2O-containing fluid stream to produce oxygen gas, hydrogen ions, and electrons;

transferring at least some of the hydrogen ions through a first electrolyte to a first cathode containing a catalyst;

in the first cathode, catalytically reducing the at least some of the hydrogen ions transferred through the first electrolyte to produce a second gas stream having hydrogen gas;

introducing the second gas stream having the hydrogen gas to a second anode having a catalyst;

in the second anode, catalytically oxidizing at least some of the hydrogen gas in the second gas stream to produce hydrogen ions and electrons;

transferring at least some of the hydrogen ions produced at the second anode through a second electrolyte to a second cathode; and

in the second cathode, catalytically reducing the at least some of the hydrogen ions transferred through the second electrolyte to produce a third gas stream having hydrogen gas.

54. The method as recited in claim 53, wherein the method further comprises removing at least some of the second gas stream to produce a modified gas stream having a non-hydrogen gas partial pressure.

55. The method as recited in claim 54, wherein introducing the second gas stream to the second anode comprises introducing the modified gas stream to the second anode.

56. The method as recited in claim 55, wherein removing at least some of the second gas stream comprises removing at least some of the second gas stream though a passage between the first electrolyte and the second electrolyte.

57. The method as recited in claim 56, wherein the passage is located between the first cathode and the second anode.

58. The method as recited in claim 57, wherein the passage located between the first cathode and the second anode comprises voids between mating surfaces of the first cathode and the second anode.

59. The method as recited in claim 57 or claim 58, wherein removing the at least some of the second gas stream comprises removing the at least some of the second gas stream through a gas-diffusion layer (GDL) positioned between the first cathode and the second anode.

60. The method as recited in any one of claims 57 to 59, wherein removing the at least some of the second gas stream comprises removing the at least some of the second gas stream though at least one channel in a surface of at least one of the first cathode and the second anode.

61. The method as recited in any one of claims 53 to 60, wherein the method further comprises introducing some hydrogen gas to the second gas stream.

62. The method as recited in any one of claims 54 to 61, wherein the method further comprises introducing some hydrogen gas to the second gas stream to replenish at least some hydrogen gas removed from the second gas stream.