Background

Fuel cells, fuel cell systems and interconnects for fuel cells and fuel cell systems remain an area of interest. Some existing systems have various shortcomings, drawbacks, and disadvantages relative to certain applications. Accordingly, there remains a need for further contributions in this area of technology.

Summary

~~The~~Embodiments of the present invention include~~s~~ a fuel cell system having an interconnect that reduces or eliminates diffusion (leakage) of fuel and oxidant by providing an increased densification, by forming the interconnect as a ceramic/metal composite.

According to a first aspect of the present invention, there is provided a fuel cell system, comprising: a plurality of electrochemical cells, each electrochemical cell including an anode, a cathode spaced apart from the anode, and an electrolyte disposed between the anode and the cathode; and a plurality of interconnects, each interconnect being configured to conduct free electrons between electrochemical cells, wherein each interconnect includes at least one pre-mixed and sintered layer of a ceramic/metal composite; wherein the ceramic/metal composite is formed as a mixture of an electronically conductive ceramic phase and a metallic phase; and wherein the metallic phase is formed by one or more precious metals and/or one or more precious metal alloys, wherein, for each interconnect, the electronically conductive ceramic phase content is in the range of approximately 70-99v %, and the one or more precious metals and/or one or more precious metal alloys content is less than approximately 30v %.

According to a second aspect of the present invention, there is provided a fuel cell system, comprising: a plurality of electrochemical cells in the form of solid oxide fuel cells; and a plurality of interconnects, each interconnect being configured to conduct free electrons between adjacent electrochemical cells; wherein each interconnect is formed solely as a pre-mixed and sintered layer of a ceramic/metal composite; wherein the ceramic/metal composite is formed as a mixture of an electronically conductive ceramic phase and a metallic phase; and wherein the metallic phase is formed by one or more precious metals and/or one or more precious metal alloys, wherein, for each

interconnect, the electronically conductive ceramic phase content is in the range of approximately 70-99v %, and the one or more precious metals and/or one or more precious metal alloys content is less than approximately 30v %.

According to a third aspect of the present invention, there is provided a method of making a fuel cell system, comprising: forming a plurality of electrochemical cells; and forming therewith a plurality of interconnects configured to conduct free electrons between adjacent electrochemical cells, wherein each interconnect is formed by: pre-mixing an electronically conductive ceramic phase with a metallic phase to form a mixture, wherein the metallic phase is formed by one or more precious metals and/or one or more precious metal alloys, and wherein the electronically conductive ceramic phase content of the mixture is in the range of approximately 70-99v %, and the one or more precious metals and/or one or more precious metal alloys content of the mixture is less than approximately 30v %; printing the mixture; and sintering the mixture.

According to a fourth aspect of the present invention, there is provided a fuel cell system, comprising: a plurality of electrochemical cells, each electrochemical cell including an anode, a cathode spaced apart from the anode, and an electrolyte disposed between the anode and the cathode; a plurality of interconnects, each interconnect being configured to conduct free electrons between electrochemical cells, wherein each interconnect includes at least one pre-mixed and sintered layer of a ceramic/metal composite; wherein the ceramic/metal composite is formed as a mixture of an electronically conductive ceramic phase and a metallic phase; and wherein the metallic phase is formed by one or more precious metals and/or one or more precious metal alloys; an anode current collector electrically coupled to each anode; and a cathode current collector electrically coupled to each cathode, wherein the interconnect is disposed between and in contact with both an anode current collector of one electrochemical cell and a cathode current collector of an adjacent electrochemical cell in a first direction, and is disposed between an electrolyte of one electrochemical cell and an electrolyte of an adjacent electrochemical cell in a second direction; and a porous substrate tube and a porous anode barrier, wherein the porous anode barrier is disposed between each anode current collector and the porous substrate tube.

Claims

What is claimed is:

1. A fuel cell system, comprising:

a plurality of electrochemical cells, each electrochemical cell including an anode, a cathode spaced apart from the anode, and an electrolyte disposed between the anode and the cathode; and

a plurality of interconnects, each interconnect being configured to conduct free electrons between electrochemical cells, wherein each interconnect includes at least one pre-mixed and sintered layer of a ceramic/metal composite; wherein the ceramic/metal composite is formed as a mixture of an electronically conductive ceramic phase and a metallic phase; and wherein the metallic phase is formed by one or more precious metals and/or one or more precious metal alloys.

2. The fuel cell system of claim 1, wherein the electrochemical cells are arranged as a segmented-in-series configuration.

3. The fuel cell system of claim 1, wherein the electrochemical cells are solid oxide fuel cells.

4. The fuel cell system of claim 1, wherein the interconnect is configured to have a porosity of approximately 5% or less.

5. The fuel cell system of claim 1, wherein the one or more precious metals and/or one or more precious metal alloys of the at least one pre-mixed and sintered layer are configured to fill pore spaces in the electronically conductive ceramic phase of the at least one pre-mixed and sintered layer.

6. The fuel cell system of claim 1, further comprising an anode current collector electrically coupled to each anode; and a cathode current collector electrically coupled to each cathode, wherein the interconnect is disposed between and in contact with both an anode current collector of one electrochemical cell and a cathode current

collector of an adjacent electrochemical cell in a first direction, and is disposed between an electrolyte of one electrochemical cell and an electrolyte of an adjacent electrochemical cell in a second direction.

7. The fuel cell system of claim 6, further comprising a porous substrate tube and a porous anode barrier, wherein the porous anode barrier is disposed between each anode current collector and the porous substrate tube.

8. The fuel cell system of claim 1, wherein the electronically conductive ceramic phase includes a doped lanthanum chromite $[(La_{1-x}A_x)(Cr_{1-y}B_y)O_3]$.

9. The fuel cell system of claim 8, wherein the electronically conductive ceramic phase includes a doped yttrium chromite $[(Y_{1-x}A_x)(Cr_{1-y}B_y)O_3]$.

10. The fuel cell system of claim 1, wherein the electronically conductive ceramic phase includes doped strontium titanate $[(Sr_{1-x}A_x)(Ti_{1-y}B_y)O_3]$.

11. The fuel cell system of claim 1, wherein the electronically conductive ceramic phase includes $(La_{1-x}Sr_x)(Ti_{1-y}Mn_yO_3)$.

12. The fuel cell system of claim 1, wherein the precious metals are one or more of Ag, Au, Pd and Pt.

13. The fuel cell system of claim 1, wherein the precious metal alloys are one or more of Ag-Pd, Ag-Pt, Au-Pd and Au-Pt.

14. A fuel cell system, comprising:

a plurality of electrochemical cells in the form of solid oxide fuel cells; and

a plurality of interconnects, each interconnect being configured to conduct free electrons between adjacent electrochemical cells; wherein each interconnect is formed solely as a pre-mixed and sintered layer of a ceramic/metal composite; wherein the

ceramic/metal composite is formed as a mixture of an electronically conductive ceramic phase and a metallic phase; and wherein the metallic phase is formed by one or more precious metals and/or one or more precious metal alloys.

15. The fuel cell system of claim 14, wherein the electronically conductive ceramic phase includes a doped lanthanum chromite.

16. The fuel cell system of claim 15, wherein the doped lanthanum chromite is LSCM ($La_{1-x}Sr_xCr_{1-y}Mn_yO_3$).

17. The fuel cell system of claim 14, wherein the electronically conductive ceramic phase includes doped strontium titanate ($SrTiO_3$) and/or ($La_{1-x}Sr_x$)($Ti_{1-y}Mn_yO_3$).

18. The fuel cell system of claim 14, wherein the precious metals are one or more of Ag, Au, Pd and Pt; and wherein the precious metal alloys are one or more of Ag-Pd, Ag-Pt, Au-Pd and Au-Pt.

19. The fuel cell system of claim 14, wherein, for each interconnect, the electronically conductive ceramic phase content is in the range of approximately 80-99v%; and the one or more precious metals and/or one or more precious metal alloys content is in the range of approximately 1-20v%.

20. The fuel cell system of claim 14, wherein for each interconnect, the one or more precious metals and/or one or more precious metal alloys content is in the range of approximately 30v% or more.

21. The fuel cell system of claim 14, wherein the metallic phase may comprise some content of non-precious metals, such as CU in addition to the one or more precious metals and/or one or more precious metal alloys.

22. A method of making a fuel cell system, comprising:

forming a plurality of electrochemical cells; and

forming therewith a plurality of interconnects configured to conduct free electrons between adjacent electrochemical cells, wherein each interconnect is formed by pre-mixing an electronically conductive ceramic phase with a metallic phase, wherein the metallic phase is formed by one or more precious metals and/or one or more precious metal alloys; printing the mixture; and sintering the mixture.

CLAIMS:

1. A fuel cell system, comprising:

a plurality of electrochemical cells, each electrochemical cell including an anode, a cathode spaced apart from the anode, and an electrolyte disposed between the anode and the cathode; and

a plurality of interconnects, each interconnect being configured to conduct free electrons between electrochemical cells, wherein each interconnect includes at least one pre-mixed and sintered layer of a ceramic/metal composite; wherein the ceramic/metal composite is formed as a mixture of an electronically conductive ceramic phase and a metallic phase; and wherein the metallic phase is formed by one or more precious metals and/or one or more precious metal alloys,

wherein, for each interconnect, the electronically conductive ceramic phase content is in the range of approximately 70-99v %, and the one or more precious metals and/or one or more precious metal alloys content is less than approximately 30v %.

2. The fuel cell system of claim 1, wherein the electrochemical cells are arranged as a segmented-in-series configuration.

3. The fuel cell system of claim 1, wherein the electrochemical cells are solid oxide fuel cells.

4. The fuel cell system of claim 1, wherein the interconnect is configured to have a porosity of approximately 5% or less.

5. The fuel cell system of claim 1, wherein the one or more precious metals and/or one or more precious metal alloys of the at least one pre-mixed and sintered layer are configured to fill pore spaces in the electronically conductive ceramic phase of the at least one pre-mixed and sintered layer.

6. The fuel cell system of claim 1, further comprising an anode current collector electrically coupled to each anode; and a cathode current collector electrically coupled to each cathode, wherein the interconnect is disposed between and in contact with both an anode current collector of one electrochemical cell and a cathode current collector of an adjacent

electrochemical cell in a first direction, and is disposed between an electrolyte of one electrochemical cell and an electrolyte of an adjacent electrochemical cell in a second direction.

7. The fuel cell system of claim 6, further comprising a porous substrate tube and a porous anode barrier, wherein the porous anode barrier is disposed between each anode current collector and the porous substrate tube.

8. The fuel cell system of claim 1, wherein the electronically conductive ceramic phase includes a doped lanthanum chromite $[(La_{1-x}A_x)(Cr_{1-y}B_y)O_3]$, wherein A is Ca or Sr; B is Mn, V, Ti, Fe, Co, Ni, Cu or Zn; x is less than 0.4; and y is less than or equal to 0.5.

9. The fuel cell system of claim 8, wherein the electronically conductive ceramic phase includes a doped yttrium chromite $[(Y_{1-x}A_x)(Cr_{1-y}B_y)O_3]$, wherein A is Ca or Sr; B is Mn, V, Ti, Fe, Co, Ni, Cu or Zn; x is less than 0.4; and y is less than or equal to 0.5.

10. The fuel cell system of claim 1, wherein the electronically conductive ceramic phase includes doped strontium titanate $[(Sr_{1-x}A_x)(Ti_{1-y}B_y)O_3]$, wherein A is La, Y or Yb; B is Mn, V, Ti, Fe, Co, Ni, Cu or Zn; x is less than 0.4; and y is less than or equal to 0.5.

11. The fuel cell system of claim 1, wherein the electronically conductive ceramic phase includes $(La_{1-x}Sr_x)(Ti_{1-y}Mn_yO_3)$, wherein x is less than 0.4, and y is less than or equal to 0.5.

12. The fuel cell system of claim 1, wherein the precious metals are one or more of Ag, Au, Pd and Pt.

13. The fuel cell system of claim 1, wherein the precious metal alloys are one or more of Ag-Pd, Ag-Pt, Au-Pd, Au-Pt and Pd-Pt.

14. A fuel cell system, comprising:

a plurality of electrochemical cells in the form of solid oxide fuel cells; and

a plurality of interconnects, each interconnect being configured to conduct free electrons between adjacent electrochemical cells; wherein each interconnect is formed solely as a pre-mixed and sintered layer of a ceramic/metal composite; wherein the ceramic/metal composite is formed as a mixture of an electronically conductive ceramic phase and a metallic phase; and

wherein the metallic phase is formed by one or more precious metals and/or one or more precious metal alloys,

wherein, for each interconnect, the electronically conductive ceramic phase content is in the range of approximately 70-99v %, and the one or more precious metals and/or one or more precious metal alloys content is less than approximately 30v %.

15. The fuel cell system of claim 14, wherein the electronically conductive ceramic phase includes a doped lanthanum chromite.

16. The fuel cell system of claim 15, wherein the doped lanthanum chromite is LSCM ($La_{1-x}Sr_xCr_{1-y}Mn_yO_3$), wherein x is less than 0.4, and y is less than or equal to 0.5.

17. The fuel cell system of claim 14, wherein the electronically conductive ceramic phase includes doped strontium titanate ($SrTiO_3$) and/or ($La_{1-x}Sr_x$)($Ti_{1-y}Mn_yO_3$), wherein x is less than 0.4, and y is less than or equal to 0.5.

18. The fuel cell system of claim 14, wherein the precious metals are one or more of Ag, Au, Pd and Pt; and wherein the precious metal alloys are one or more of Ag-Pd, Ag-Pt, Au-Pd, Au-Pt and Pd-Pt.

19. The fuel cell system of claim 14, wherein, for each interconnect, the electronically conductive ceramic phase content is in the range of approximately 80-99v %; and the one or more precious metals and/or one or more precious metal alloys content is in the range of approximately 1-20v %.

20. The fuel cell system of claim 14, wherein for each interconnect, the one or more precious metals and/or one or more precious metal alloys content is in the range of approximately 30v % or more.

21. The fuel cell system of claim 14, wherein the metallic phase is formed by Cu and/or Mn in addition to the one or more precious metals and/or one or more precious metal alloys.

22. A method of making a fuel cell system, comprising:

forming a plurality of electrochemical cells; and

forming therewith a plurality of interconnects configured to conduct free electrons between adjacent electrochemical cells, wherein each interconnect is formed by:

pre-mixing an electronically conductive ceramic phase with a metallic phase to form a mixture, wherein the metallic phase is formed by one or more precious metals and/or one or more precious metal alloys, and wherein the electronically conductive ceramic phase content of the mixture is in the range of approximately 70-99v %, and the one or more precious metals and/or one or more precious metal alloys content of the mixture is less than approximately 30v %;

printing the mixture; and

sintering the mixture.

23. A fuel cell system, comprising:

a plurality of electrochemical cells, each electrochemical cell including an anode, a cathode spaced apart from the anode, and an electrolyte disposed between the anode and the cathode;

a plurality of interconnects, each interconnect being configured to conduct free electrons between electrochemical cells, wherein each interconnect includes at least one pre-mixed and sintered layer of a ceramic/metal composite; wherein the ceramic/metal composite is formed as a mixture of an electronically conductive ceramic phase and a metallic phase; and wherein the metallic phase is formed by one or more precious metals and/or one or more precious metal alloys;

an anode current collector electrically coupled to each anode; and

a cathode current collector electrically coupled to each cathode, wherein the interconnect is disposed between and in contact with both an anode current collector of one electrochemical cell and a cathode current collector of an adjacent electrochemical cell in a first direction, and is disposed between an electrolyte of one electrochemical cell and an electrolyte of an adjacent electrochemical cell in a second direction; and

a porous substrate tube and a porous anode barrier, wherein the porous anode barrier is disposed between each anode current collector and the porous substrate tube.