environments during fuel cell operation; and nonporous, in order to prevent diffusion of the fuel and/or oxidant through the interconnect. If the interconnect is porous, fuel may diffuse to the oxidant side and burn, resulting in local hot spots that may result in a reduction of fuel cell life, e.g., due to degradation of materials and mechanical failure, as well as reduced efficiency of the fuel cell system. Similarly, the oxidant may diffuse to the fuel side, resulting in burning of the fuel. Severe interconnect leakage may significantly reduce the fuel utilization and performance of the fuel cell, or cause catastrophic failure of fuel cells or stacks.

**[0024]** In accordance with one or more examples of the disclosure, interconnect 16 may include two or more layers of different compositions, e.g., first CIC portion 50 and second CIC portion 52. The composition of the interconnect layer nearest cathode 28 and cathode conductive layer 30 (i.e., first CIC portion 50~~52~~ in FIG. 2) may be tailored to have properties suitable for the oxidant side, such as, a material that is stable and compatible with cathode side materials under air stream, high $pO_2$. Conversely, the composition of the interconnect layer nearest anode 24 and anode conductive layer 22 (i.e., second CIC portion 52 in FIG. 2) may be tailored to have properties suitable for the fuel side, such as, a material that stable and compatible with anode side materials under fuel environment, low $pO_2$. With the configuration shown in FIG. 2 of interconnect 16, interconnect 16 may allow for current flow through the thickness of the interconnect film. This may be desirable in case in which interconnect is formed of ceramic materials, e.g., as compared to precious metal or cermet, due to the comparatively lower conductivity. Such a configuration may be designed to reduce ohmic resistance from bi-layer interconnect 16.

**[0025]** Anode conductive layer 22 may be an electrode conductive layer formed of a nickel cermet, such as such as Ni-YSZ (e.g., where yttria doping in zirconia is 3-8 mol%,), Ni-ScSZ (e.g., where scandia doping is 4-10 mol%, preferably including a second doping for example 1 mol% ceria for phase stability for 10 mol% scandia-$ZrO_2$) and/or Ni-doped ceria (such as Gd or Sm doping), doped lanthanum chromite (such as Ca doping on A site and Zn doping on B site), doped strontium titanate (such as La doping on A site and Mn doping on B site) , $La_{1-x}Sr_xMn_yCr_{1-y}O_3$ and/or Mn-based R-P phases of the general formula a $(La_{1-x}Sr_x)_{n+1}Mn_nO_{3n+1}$

## CLAIMS:

1. A fuel cell comprising:

a first electrochemical cell including a first anode and a first cathode;

a second electrochemical cell including a second anode and a second cathode; and

~~an~~ ceramic interconnect configured to conduct a flow of electrons from the first anode to the second cathode, wherein the interconnect comprises a first ceramic layer~~portion~~ and a second ceramic layer~~portion~~ adjacent the first ceramic layer, wherein the first ceramic layer~~portion~~ is closer to the first anode than the second ceramic layer~~portion~~, and the second ceramic layer~~portion~~ is closer to the second cathode than the first ceramic layer~~portion~~, wherein the first ceramic layer and second ceramic layer separate fuel gas on an anode side of the fuel cell from oxidant gas on a cathode side of the fuel cell,

wherein the first ceramic layer~~portion~~ comprises one or more of doped ceria, doped lanthanum chromite, and doped yttrium chromite, and

wherein the second ceramic layer~~portion~~ comprises one or more of a Co-Mn spinel and a $ABO_3$ perovskite.

2. The fuel cell of claim 1, wherein the first ceramic layer~~portion~~ comprises doped ceria having the chemical formula $(R_xCe_{1-x})O_2$, where R is a rare earth metal, $0 < x \leq 0.5$.

3. The fuel cell of claim 1, wherein the first ceramic layer~~portion~~ comprises doped ceria having the chemical formula $(R_x M_y Ce_{1-x-y})O_2$, where R is a rare earth metal, M is a transition metal, $0 < x \leq 0.5$ and $0 \leq y < 0.1$.

4. The fuel cell of claim 1, wherein the first ceramic layer~~portion~~ comprises doped ceria having the chemical formula $w(R_x M_y Ce_{1-x-y})O_2 - (1-w)N$, where R is a rare earth

metal, M is a transition metal, N is an alkali metal or alkaline earth metal, $0 < x \leq 0.5$, $0 \leq y < 0.1$, and $0 < w \leq 0.1$.

5. The fuel cell of claim 1, wherein the first ceramic layer~~portion~~ comprises a doped ceria-perovskite composite material.

6. The fuel cell of claim 5, wherein the perovskite comprises $SrTiO_3$ or $(Sr_{1-x}A_x)(Ti_{1-y}M_y)O_3$, where A is an alkaline metal or rare earth metal, and M is a transition metal.

7. The fuel cell of claim 5, wherein the perovskite comprises doped lanthanum chromite having the chemical formula $(La_{1-x}A_x)(Cr_{1-y}M_y)O_3$, where A is an alkaline metal, M is a transition metal, and $0 < x \leq 0.3$.

8. The fuel cell of claim 1, wherein the first ceramic layer~~portion~~ comprises doped lanthanum chromite having the chemical formula $(La_{1-x}A_x)(Cr_{1-y}M_y)O_3$, where A is an alkaline metal, M is a transition metal, and $0 < x \leq 0.3$, $0 < y \leq 0.5$.

9. The fuel cell of claim 1, wherein the second ceramic layer~~portion~~ comprises a $(Mn,Co, A)_3O_4$ spinel, where A is a transition metal.

10. The fuel cell of claim 1, wherein the second ceramic layer~~portion~~ comprises the $ABO_3$ perovskite, wherein the $ABO_3$ perovskite comprises one or more of LSM ($(La_{1-x}Sr_x)MnO_3$), LNF ($La(Ni_{1-y}Fe_y)O_3$, PSM ($(Pr_{1-x}Sr_x)MnO_3$), LSC ($(La_{1-x}Sr_x)CoO_3$), LSCF ($(La_{1-x}Sr_x)(Co_{1-y}Fe_y)O_3$), and R-P nickelate, such as $Pr_2NiO_4$.

11. The fuel cell of claim 1, wherein the second ceramic layer~~portion~~ comprises a $(Mn,Co, A_x)_3O_4$ spinel - $ABO_3$ perovskite composite, where A is a transition metal, and $0 \leq x \leq 0.1$.

12. The fuel cell of claim 11, wherein the composite comprises one or more of (Mn, Co, $A_x)_3O_4$ – LNF and (Mn, Co, $A_x)_3O_4$ – LSM.

13. The fuel cell of claim 1, wherein the second ceramic layer~~portion~~ comprises a (Mn, Co, $A_x)_3O_4$ spinel – ionic phase composite, where A is a transition metal, and $0 \leq x \leq 0.1$.

14. The fuel cell of claim 13, wherein the ionic phase comprises one or more of doped ceria, Y or Sc stabilized zirconia.

15. The fuel cell of claim 1, wherein the first ceramic layer and the second ceramic layer are adjacent each other along an interface, wherein the first ceramic layer~~portion~~ defines a first thickness and the second ceramic layer~~portion~~ defines a second thickness, wherein the first thickness and~~of first portion may be thinner or thicker than, or same as,~~ second thickness~~portion, depending on the materials used, to~~ control the $pO_2$ at the interface of the first and second ceramic layers~~portions~~ in a~~desired~~ range of $1.01325e^{-6}$ to $1.01325e^{-9}$ pascal.

16. The fuel cell of claim 1, wherein the first ceramic layer~~portion~~ defines a first thickness and the second ceramic layer~~portion~~ defines a second thickness, wherein the first thickness is in the range of about 5 to about 100 micrometers~~microns~~, and the second thickness is in the range of about 5 to about 50 micrometers~~microns~~.

17. The fuel cell of claim 1, wherein the second ceramic layer~~portion~~ comprises a $(Mn,Co)_3O_4$ spinel.

18. A method for manufacturing a fuel cell, the method comprising forming a fuel cell structure, the structure comprising:

a first electrochemical cell including a first anode and a first cathode;

a second electrochemical cell including a second anode and a second cathode; and

~~an~~ ceramic interconnect configured to conduct a flow of electrons from the first anode to the second cathode, wherein the interconnect comprises a first ceramic layer~~portion~~ and a second ceramic layer~~portion~~ adjacent the first ceramic layer, wherein the first ceramic layer~~portion~~ is closer to the anode than the second ceramic layer~~portion~~, and the second ceramic layer~~portion~~ is closer to the cathode than the first ceramic layer~~portion~~, wherein the first ceramic layer and second ceramic layer separate fuel gas on an anode side of the fuel cell from oxidant gas on the cathode side of the fuel cell,

wherein the first ceramic layer~~portion~~ comprises one or more of doped ceria, doped lanthanum chromite, and doped yttrium chromite, and

wherein the second ceramic layer~~portion~~ comprises one or more of a Co-Mn spinel and a $ABO_3$ perovskite.

~~19. A method comprising controlling operation of a fuel cell to generate electricity, wherein the fuel cell comprises:~~

~~a first electrochemical cell including a first anode and a first cathode;~~

~~a second electrochemical cell including a second anode and a second cathode; and~~

~~an interconnect configured to conduct a flow of electrons from the first anode to the second cathode, wherein the interconnect comprises a first portion and a second portion, wherein the first portion is closer to the anode than the second portion, and the second portion is closer to the cathode than the first portion,~~

~~wherein the first portion comprises one or more of doped ceria, doped lanthanum chromite, and doped yttrium chromite, and~~

~~wherein the second portion comprises one or more of a Co-Mn spinel and a $ABO_3$ perovskite.~~