Summary

[0007] Accordingly, the present disclosure provides an interconnect for a low temperature solid oxide fuel cell, the interconnect comprising:

a stainless steel substrate comprising a first surface and a second surface;

a layer comprising chromium oxide on the first surface of the substrate, wherein the chromium oxide layer is of thickness in the range 350 – 600nm; and

a metal oxide coating on the chromium oxide layer.

[0007a] In a first aspect of the present disclosure, there is provided an interconnect for a low temperature solid oxide fuel cell, the interconnect comprising:

a stainless steel substrate comprising a first surface and a second surface;

a layer comprising chromium oxide on the first surface of the substrate, wherein the chromium oxide layer is of thickness in the range 350 – 600nm; and

a metal oxide coating on the chromium oxide layer; wherein the interconnect further comprises an alumina layer on the second surface of the substrate.

[0008] For the avoidance of doubt, as used herein the term "low temperature solid oxide fuel cell" is intended to refer to a solid oxide fuel cell which operates at a temperature in the range 450 – 650°C, more often in the range 500 – 620°C, or 520 – 570°C. This is as opposed to conventional solid oxide fuel cells which operate at temperatures in excess of 650°C, often in excess of 700°C. The interconnect is protected from corrosion by the chromium oxide layer. The prevention of corrosion ensuring that structural integrity of the interconnect is maintained during the lifetime of the fuel cell stack. This allows the interconnect to perform its support function, and minimises porosity of the interconnect, ensuring that the fuel and oxidant gases cannot mix.

[0009] The interconnect above has the advantage in that it overcomes a problem of low temperature SOFC operation, in that current collection on the cathode side is typically

through the chromium oxide layer on the steel adjacent the interconnect. As chromia is a semi-conductor, its electronic conductivity increases exponentially with increasing temperature. Thus, at the operating temperatures of low temperature SOFC's the resistance of a given thickness of chromia will be many times that observed at conventional higher temperature SOFC operating temperatures. It therefore becomes increasingly important in low temperature systems that the chromia scale is no thicker than necessary to protect the steel. The applicant has found that an optimum balance of corrosion protection relative to resistance is in the range 350 – 600nm, often 350 – 500nm, or 350 – 450nm.

[0010] As used herein the term "layer" is intended to refer to complete layers of the substance described, such that where the layer is a coating, the coating will cover

cobalt oxide, as at low temperatures (<900°C), cobalt oxide is significantly more conductive than chromia, tends to form dense layers (thus preventing chromium evaporation), is not thought to be poisonous to the fuel cell cathode and does not react with the steel substrate of the metal supported fuel cell. It can also be formed by the oxidation of metallic cobalt, whereas more complex oxides (usually manganese-cobalt mixed oxides) can be harder to deposit in metallic form. However, any electrically conductive, non-volatile coating which can be made sufficiently dense to prevent chromium evaporation from the surface of the steel may be used. Ceria may be added to the coating, and has the advantage that it inhibits the oxide growth kinetics allowing the use of steel substrates containing lower concentrations of chromium. Often the metal oxide coating is of thickness in the range 0.5 – 20 μm, at these thicknesses chromium evaporation can be prevented, without unnecessarily increasing the thickness of the interconnect structure.

[0016] A cathode contact paste or contact layer could be applied to the interconnect of the present disclosure in instances where a reduction in the contact resistance between the interconnect and the cathode of the SOFC is required.

[0016a] In a second aspect of the present disclosure, there is provided a process of making an interconnect for a low temperature solid oxide fuel cell according to the first aspect of the present disclosure, the process comprising:

a) coating the first surface of the stainless steel substrate with the metal oxide to form the coated substrate; and

b) heating the coated substrate to a temperature in the range 800 – 920°C to form a layer comprising chromium oxide between the first surface and the metal oxide coating and a layer of alumina on the second surface.

[0017] The present disclosure also provides a process for making an interconnect for a low temperature solid oxide fuel cell, the process comprising:

coating a first surface of a stainless steel substrate with a metal oxide to form a coated substrate; and

heating the coated substrate to a temperature in the range 800 – 920°C, often 800 – 890°C to form a layer comprising chromium oxide between the first surface and the metal

layer, which may not form immediately upon first operation of the stack, the delay leading to oxidation (i.e. rusting) of the substrate This could lead to reduced electrical conductivity of the interconnect and so reduced current collection.

[0018] Often the coated substrate is heated for a time in the range 3 – 6 hours. Heating for this time is sufficient to ensure formation of the chromium oxide layer, without degradation to the components of the interconnect and can be advantageous from a manufacturing point of view as the process can be run overnight or within a typical shift pattern, with the furnace being cool enough to open and reload for the next shift. However, the optimal heating time will depend upon the steel substrate and will change from batch to batch.

[0019] The coating may be applied using one of many known methods, including a method selected from, vapour deposition, printing, roll-to-roll processing, spray coating, or combinations thereof. Often the method used will be as described in US 2009/0029187 (Schuisky et al.), the subject matter of which is herein incorporated by reference in its entirety in as far as it relates to the method of producing the product. For instance, the method may comprise providing a metallic layer and a reactive layer on the stainless steel substrate, allowing the metallic layer and reactive layer to react with each other or diffuse into each other, and oxidising the metallic layer and reactive layer to form the metal oxide coating.

[0020] The coating of the first surface of the stainless steel substrate with the metal oxide forms a coated substrate, which may then either be processed to provide a coated interconnect form, which is then heated as described, or which is heated as described, prior to processing to form the interconnect from the heat treated coated substrate.

[0021] The present disclosure also provides an interconnect made using the process according to the second aspect of the present disclosure. In a third aspect of the present disclosure, there is provided a fuel cell stack comprising at least one interconnect according to the first aspect of the present disclosure. Often, in the fuel cell stack, the metal oxide coating is in contact with the air supplying the fuel cell. In a fourth aspect of the present disclosure, there is provided the use of a fuel cell stack of the third aspect of the present disclosure in the generation of electrical energy.

[0022] An interconnect for a low temperature solid oxide fuel cell, the interconnect comprising:

a stainless steel substrate comprising a first surface and a second surface, wherein the stainless steel comprises 17 – 25 wt% chromium, and is a ferritic stainless steel;

a layer comprising chromium oxide on the first surface of the substrate, wherein the chromium oxide layer is an oxide scale of thickness in the range 350 – 600nm;

a metal oxide coating on the chromium oxide layer, wherein the metal oxide is selected from cobalt oxide, manganese cobalt oxide, copper oxide or combinations thereof and is of thickness in the range 0.5 – 20 μm; and

an aluminium oxide layer on the second surface of the substrate.

[0023] A process for making an interconnect for a low temperature solid oxide fuel cell, the process comprising:

coating a first surface of a stainless steel substrate to be used for the interconnect with a metal oxide using a method selected from, vapour deposition, printing, roll-to-roll processing, spray coating, or combinations thereof to form a coated substrate; and

either forming the interconnect from the coated interconnect substrate to generate a coated interconnect form; and then

heating the coated interconnect form to a temperature in the range 800 – 920°C for a time in the range 3 – 6 hours to form a layer comprising chromium oxide between the first surface and the metal oxide coating; or

heating the coated substrate to a temperature in the range 800 – 920°C for a time in the range 3 – 6 hours to form a layer comprising chromium oxide between the first surface and the metal oxide coating; and then

forming the interconnect from the heat treated coated substrate.

Claims

1. An interconnect for a low temperature solid oxide fuel cell, the interconnect comprising:

a stainless steel substrate comprising a first surface and a second surface;

a layer comprising chromium oxide on the first surface of the substrate, wherein the chromium oxide layer is of thickness in the range 350 - 600nm; and

a metal oxide coating on the chromium oxide layer; wherein the interconnect further comprises an alumina layer on the second surface of the substrate.

2. An interconnect according to claim 1, wherein the chromium oxide layer is an oxide scale.

3. An interconnect according to claim 1 or claim 2, wherein the stainless steel comprises 17 - 25 wt% chromium.

4. An interconnect according to claim 3, wherein the stainless steel is a ferritic stainless steel.

5. An interconnect according to any preceding claim, wherein the metal oxide comprises a metal oxide selected from cobalt oxide, manganese cobalt oxide, copper oxide or combinations thereof.

6. An interconnect according to any preceding claim, wherein the metal oxide coating is of thickness in the range 0.5 - 20 μm.

7. A process of making an interconnect for a low temperature solid oxide fuel cell according to any of claims 1 to 6, the process comprising:

a) coating the first surface of the stainless steel substrate with the metal oxide to form the coated substrate; and

b) heating the coated substrate to a temperature in the range 800 - 920°C to form a layer comprising chromium oxide between the first surface and the metal oxide coating and a layer of alumina on the second surface.

8. A process according to claim 7, wherein the coated substrate is heated for a time in the range 3 - 6 hours.

9. A process according to claim 7 or claim 8, wherein the coating is applied to the substrate by a method selected from, vapour deposition, printing, roll-to-roll processing, spray coating, or combinations thereof.

10. A process according to any of claims 7 to 9, wherein the coating is applied to the substrate by a method comprising providing a metallic layer and a reactive layer on the stainless steel substrate, allowing the metallic layer and reactive layer to react with each other or diffuse into each other, and oxidising the metallic layer and reactive layer to form the metal oxide coating.

11. A process according to any of claims 7 to 10, wherein an interconnect form is provided by processing either prior to heating the coated substrate, or after heating the coated substrate.

12. A fuel cell stack comprising at least one interconnect according to any of claims 1 to 6.

13. A fuel cell stack according to claim 12, wherein the metal oxide coating is in contact with the air supplying the fuel cell.

14. A fuel cell stack according to claim 12 or claim 13 wherein a cathode contact paste, or contact layer is present between the cathode and a cathode side of at least one interconnect.

15. Use of a fuel cell stack according to claim 12 or claim 14 in the generation of electrical energy.