CLAIMS

1. A bipolar plate for a hydrogen fuel cell (e.g. a PEM hydrogen fuel cell), coated with a carbon-containing coating, the carbon-containing coating comprising in order:

a) a titanium seed layer;

b) a titanium nitride interfacial layer; and

c) a a-C top layer,

and wherein the coating has a thickness of less than 1.5µm and the bipolar plate is formed from stainless steel.

~~2. A bipolar plate according to claim 1, wherein the bipolar plate is for a PEM hydrogen fuel cell.~~

2~~3~~. A bipolar plate according to ~~any of~~ claim~~s~~ 1 ~~or 2~~, wherein the layer of a-C has a volumetric density of greater than 2.5 g/cm^3, for example greater than 3.0 g/cm^3, preferably 3.5 g/cm^3 or greater.

~~4. A bipolar plate according to any preceding claim, wherein the titanium nitride interfacial layer and a-C top layer are adjacent.~~

~~5. A bipolar plate according to any preceding claim, wherein the titanium seed layer and titanium nitride interfacial layer are adjacent.~~

~~6. A bipolar plate according to any preceding claim, wherein the bipolar plate and titanium seed layer are adjacent.~~

~~7. A bipolar plate according to any preceding claim, wherein the bipolar plate and titanium seed layer are adjacent, the titanium seed layer and titanium nitride interfacial layer are adjacent, and the titanium nitride interfacial layer and a-C layer are adjacent.~~

~~8~~3. A coated bipolar plate according to any preceding claim, wherein the carbon-containing coating consists of in order:

a) a titanium seed layer;

b) a titanium nitride interfacial layer; and

c) a a-C top layer.

49. A bipolar plate according to any preceding claim, wherein the layer of a-C has a molar hydrogen content of 5% or less and/or a molar nitrogen content of 5% or less.

~~10. A bipolar plate according to any preceding claim, wherein the layer of a-C has a molar hydrogen content of 2% or less.~~

~~11. A bipolar plate according to any preceding claim, wherein the layer of a-C has a molar hydrogen content of 1% or less.~~

~~12. A bipolar plate according to any preceding claim, wherein the layer of a-C has a molar nitrogen content of 5% or less.~~

~~13. A bipolar plate according to any preceding claim, wherein the layer of a-C has a molar nitrogen content of 2% or less.~~

~~14. A bipolar plate according to any preceding claim, wherein the layer of a-C has a molar nitrogen content of 1% or less.~~

~~15. A bipolar plate according to any preceding claim, wherein the layer of a-C comprises both sp^2 carbon and sp^3 carbon.~~

~~16. A bipolar plate according to any preceding claim, wherein the layer of a-C has an sp^2 carbon content of 40% or more, preferably 50% or more.~~

~~17. A bipolar plate according to any preceding claim, wherein the layer of a-C has an sp^2 carbon content of 90% or less, preferably 80% or less.~~

518. A bipolar plate according to any preceding claim, wherein the layer of a-C has an sp^2 carbon content of 50% to 80% (e.g. an average sp^2 carbon content of about 55%).

~~19. A bipolar plate according to any preceding claim, wherein the layer of a-C has an sp^2 carbon content of 50% to 70%.~~

~~20. A bipolar plate according to any preceding claim, wherein the layer of a-C has an average sp^2 carbon content of about 55%.~~

~~21. A bipolar plate according to any preceding claim, wherein the layer of a-C has an sp^3 carbon content of 20% or more, preferably 30% or more.~~

~~22. A bipolar plate according to any preceding claim, wherein the layer of a-C has an sp^3 carbon content of 80% or less, preferably 60% or less.~~

6~~23~~. A bipolar plate according to any preceding claim, wherein the layer of a-C has an sp^3 carbon content of 30% to 60% (e.g. an average sp^3 carbon content of about 45%).

~~24. A bipolar plate according to any preceding claim, wherein the layer of a-C has an average sp^3 carbon content of about 45%.~~

~~25. A bipolar plate according to any preceding claim, wherein the layer of a-C has a hardness of 1000HV or greater.~~

~~26. A bipolar plate according to any preceding claim, wherein the layer of a-C has a hardness of 3000HV or less.~~

~~2~~7. A bipolar plate according to any preceding claim, wherein the layer of a-C has a hardness of 1500HV to 2000HV.

~~28. A bipolar plate according to any preceding claim, wherein the layer of a-C has a thickness of up to 1.0μm.~~

~~29. A bipolar plate according to any preceding claim, wherein the layer of a-C has a thickness of 0.05μm or more.~~

~~30. A bipolar plate according to any preceding claim, wherein the layer of a-C has a thickness of from 0.1µm to 0.5µm.~~

~~31. A bipolar plate according to any preceding claim, wherein the seed layer has a thickness of 0.5µm or less.~~

~~32. A bipolar plate according to any preceding claim, wherein the interfacial layer has a thickness of 0.5µm or less.~~

~~33. A bipolar plate according to any preceding claim, wherein the bipolar plate has a thickness of 0.5mm or less.~~

8~~34~~. A bipolar plate according to any preceding claim, wherein the carbon-containing coating comprises in order:

a) a titanium seed layer with a thickness of 0.5µm or less;

b) a titanium nitride interfacial layer with a thickness of 0.5µm or less; and

c) a a-C top layer with a thickness of 1.0µm or less,

and wherein the bipolar plate is formed from stainless steel and has a thickness of 0.5mm or less.

~~35. A bipolar plate according to any preceding claim, wherein the stainless steel is selected from SUS304 or 316L stainless steel.~~

9~~36~~. A bipolar plate according to any preceding claim, wherein the a-C layer has a molar hydrogen content of 5% or less, an sp^2 carbon content of 50% to 70%, and an sp^3 carbon content of 30% to 60%.

10~~37~~. A bipolar plate for a hydrogen fuel cell, coated with a carbon-containing coating, the carbon-containing coating comprising in order:

a) a seed layer comprising a metal or alloy (e.g. titanium);

b) an interfacial layer comprising a carbide or nitride of the metal / alloy in the seed layer; and

c) a top layer comprising a-C (e.g. consisting of a-C);

wherein the a-C has a density of greater than 3.0g/cm^3, a molar hydrogen content of 5% or less, an sp^2 carbon content of 40% to 70%, and an sp^3 carbon content of 30% to 60%.

11~~38~~. A bipolar plate according to claim 10~~37~~, wherein the layer of a-C has a molar hydrogen content of 2% or less.

12~~39~~. A bipolar plate according to any of claims ~~37~~ 10 to ~~38~~11, wherein the layer of a-C has an average sp^2 carbon content of about 55% and/or wherein the layer of a-C has an average sp^3 carbon content of about 45%.

~~40. A bipolar plate according to any of claims 37 to 39, wherein the layer of a-C has an average sp^3 carbon content of about 45%.~~

13~~41~~. A bipolar plate according to any of claims ~~37~~ 10 to ~~40~~12, wherein the bipolar plate is formed from stainless steel.

~~42. A bipolar plate according to any of claims 37 to 41, wherein the seed layer is or comprises titanium.~~

14~~43~~. A bipolar plate according to any of claims ~~37~~ 10 to ~~42~~13, wherein the bipolar plate and seed layer are adjacent, the seed layer and interfacial layer are adjacent, and interfacial layer and top layer comprising a-C layer are adjacent.

~~44. A bipolar plate according to any of claims 37 to 43, wherein the top layer consists of a-C.~~

~~45~~15. A bipolar plate according to any of claims ~~37~~ 10 to ~~44~~14, wherein the carbon-containing coating comprises in order:

a) a seed layer comprising a metal or alloy with a thickness of 0.5µm or less;

b) an interfacial layer comprising a carbide or nitride of the metal / alloy in the seed layer with a thickness of 0.5µm or less; and

c) a top layer comprising a-C with a thickness of 1.0µm or less;

wherein the a-C has a density of greater than 2.0g/cm^3, a molar hydrogen content of 5% or less, an sp^2 carbon content of 40% to 80%, preferably 40% to 70% and an sp^3 carbon content of 20% to 60%, preferably 30% to 60%.

~~46~~16. A hydrogen fuel cell comprising one or more bipolar plates according to any of claims 1 to ~~45~~15.

~~47~~17. A method of coating a bipolar plate for a PEM hydrogen fuel cell with a carbon-containing coating, the method comprising:

a) applying onto the plate a seed layer comprising a metal (e.g. titanium);

b) applying onto the seed layer an interfacial layer comprising a nitride or carbide of the metal; and

c) applying onto the interfacial layer a layer comprising a-C,

wherein the a-C has a density of greater than 3.0g/cm^3, a molar hydrogen content of 5% or less, an sp^2 carbon content of 40% to 80%, preferably 40% to 70% and an sp^3 carbon content of 20% to 60%, preferably 30% to 60%.

~~48. A method of coating a bipolar plate for a PEM hydrogen fuel cell according to claim 47, wherein in step (a) the seed layer is applied to the plate via a HIPIMS, DC pulse or metallic FCVA deposition process.~~

~~49. A method of coating a bipolar plate for a PEM hydrogen fuel cell according to any of claims 47 to 48, wherein the seed layer comprises titanium.~~

~~50. A method of coating a bipolar plate for a PEM hydrogen fuel cell according to any of claims 47 to 49, wherein in step (b) the interfacial layer is applied via a sputtering process.~~

~~51. A method of coating a bipolar plate for a PEM hydrogen fuel cell according to any of claims 47 to 50, wherein the interfacial layer comprises titanium nitride.~~

~~52. A method of coating a bipolar plate for a PEM hydrogen fuel cell according to any of claims 47 to 51, wherein in step (c) the layer comprising a-C is applied via an FCVA process.~~

~~53~~18. A method of coating a bipolar plate for a PEM hydrogen fuel cell with a carbon-containing coating according to any of claims ~~47~~ 10 to ~~52~~17, wherein the method comprises:

a) applying onto the plate a seed layer comprising a metal via a HIPIMS, DC pulse or metallic FCVA deposition process;

b) applying onto the seed layer an interfacial layer comprising a nitride or carbide of the metal via a sputtering process; and

c) applying onto the interfacial layer a layer comprising a-C via an FCVA process.

~~54~~19. A method of coating a bipolar plate for a PEM hydrogen fuel cell according to claim ~~53~~18, wherein the seed layer is titanium and the interfacial layer is titanium nitride.

~~55~~20. A method of coating a bipolar plate for a PEM hydrogen fuel cell according to any of claims ~~47~~ 17 to ~~54~~19, for making a bipolar plate according to any of claims 1 - ~~46~~15.