coking resistance, as coke deposition on catalyst surfaces can lead to a drop in catalytic activity and selectivity.

[0007] It is an object of the invention to at least partially satisfy the above needs.

Summary

[0008] The present inventors have identified that catalysts comprising a catalytic element, for example, metallic nickel, disposed on a ceria-based substrate lead to a significant improvement in catalytic performance when used to catalyse the methanation reaction of a feedstock, and in particular, a feedstock including sulfur, when compared with conventional catalysts.

[0009] There is provided a catalyst, comprising a catalytic element disposed on a substrate, wherein said substrate has formula $Ce_{1-x}M_xO_2$, wherein x is between about 0 and about 0.3, optionally between about 0.01 and about 0.3, and wherein M, if present, is a metallic element other than Ce, when used for catalysing a methanation reaction.

[0009a] In an aspect, there is provided a catalyst when used for catalysing a methanation reaction, said catalyst comprising: a catalytic element disposed on a substrate, wherein said substrate comprises Ce and at least one metallic element (M) selected from the group consisting of Y, Gd, Sm and alkaline earth metals; wherein said substrate has a general formula $Ce_{1-x}M_xO_2$, wherein x is the total proportion of M and is between 0.01 and 0.3, and wherein said substrate is particulate.

[00010] The following options may be used in conjunction with the above defined aspect either individually or in any suitable combination.

[00011] The catalytic element may be a metal. The metal may be a transition metal, e.g., it may be selected from the group consisting of Co, Fe, Pt, Ru, Rh, Pd, Ni and Ir. Therefore, the catalytic element may be Co, Fe, Pt, Ru, Rh, Pd, Ni or Ir. In particular, the catalytic element may be metallic, e.g., it may be metallic nickel, or may be metallic cobalt, or metallic palladium, or metallic platinum, or metallic iron, or metallic rhodium, or metallic ruthenium, or metallic iridium. In some instances it may be a mixture or alloy of any two or more of these metals, or may be a mixture or alloy of any one of these metals with some other metal.

[00012] The substrate may be particulate. The particles of the substrate may have a mean particle diameter of less than about 0.5 μm or less than about 100 nm.

[00013] In the substrate of formula $Ce_{1-x}M_xO_2$, x may be between about 0.01 and about 0.25, or may be between about 0.1 and about 0.2. For example, in the substrate of formula $Ce_{1-x}M_xO_2$, x may be about 0.01, or may be about 0.05, or may be about 0.1, or may be about 0.15, or may be

feedstock with a catalyst comprising metallic nickel disposed on a substrate, wherein said substrate has formula $Ce_{1-x}M_xO_2$, wherein x is between about 0.1 and about 0.3 and wherein M is a metallic element selected from the group consisting of a lanthanoid, a transition metal and an alkaline earth metal, wherein the feedstock includes coal gasification effluent or biomass gasification effluent and further includes a sulfur-containing gas or vapour at a concentration of about 0.1 to about 5000 ppm.

[00044] In another embodiment, the present disclosure provides a method for methanation of a feedstock including carbon monoxide and hydrogen, said method comprising contacting the feedstock with a catalyst comprising metallic nickel disposed on a substrate, wherein said substrate has formula $Ce_{0.9}M_{0.1}O_2$, (i.e., x is 0.1), and wherein M is a metallic element selected from the group consisting of Sm, Gd and Ca, wherein said substrate has a specific surface area of between about 10 and about 300 m^2/g; and wherein said substrate is particulate and the particles have a mean particle diameter of less than about 0.5 μm, wherein the feedstock includes coal gasification effluent or biomass gasification effluent and further includes a sulfur-containing gas or vapour at a concentration of about 0.1 to about 5000 ppm.

[00045] According to another embodiment of the disclosure, there is provided a method for reducing the carbon monoxide content of a gas mixture including carbon monoxide and hydrogen, said method comprising contacting the feedstock with a catalyst as defined above.

[00046] According to another embodiment, there is provided the use of a substrate of formula $Ce_{1-x}M_xO_2$, wherein x is between about 0 and about 0.3, optionally between about 0.01 and about 0.3, and wherein M, if present, is a metallic element other than Ce, for reducing poisoning of a catalytic element by a sulfur-containing gas or vapour.

[00046a] In another aspect, there is provided the use of a particulate substrate of general formula $Ce_{1-x}M_xO_2$, for reducing poisoning of a catalytic element by a sulfur-containing gas or vapour, said substrate comprising: Ce and at least one metallic element (M) selected from the group consisting of Y, Gd, Sm and alkaline earth metals, and wherein x is the total proportion of M and is between 0.01 and 0.3.

[00047] According to another embodiment, there is provided a method for reducing poisoning of a catalytic element by a sulfur-containing gas or vapour, said method comprising depositing said catalytic element on a substrate, wherein said substrate has formula $Ce_{1-x}M_xO_2$,

wherein x is between about 0 and about 0.3, optionally between about 0.01 and about 0.3, and wherein M, if present, is a metallic element other than Ce.

[00047a] In another aspect, there is provided a method for reducing poisoning of a catalytic element by a sulfur-containing gas or vapour, said method comprising: depositing said catalytic element on a particulate substrate which comprises Ce and at least one metallic element (M) selected from the group consisting of Y, Gd, Sm and alkaline earth metals; wherein said substrate has general formula $Ce_{1-x}M_xO_2$, and wherein x is the total proportion of M and is between 0.01 and 0.3.

[00048] The following options may be used in conjunction with the above aspect either individually or in any suitable combination.

CLAIMS

1. A catalyst when used for catalysing a methanation reaction, said catalyst comprising: a catalytic element disposed on a substrate, wherein said substrate comprises Ce and at least one metallic element (M) selected from the group consisting of Y, Gd, Sm and alkaline earth metals; wherein said substrate has a general formula $Ce_{1-x}M_xO_2$, wherein x is the total proportion of M and is between 0.01 and 0.3, and wherein said substrate is particulate.

2. The catalyst of claim 1 wherein the catalytic element is a transition metal.

3. The catalyst of claim 1 or claim 2 wherein the catalytic element is selected from the group consisting of Co, Fe, Pt, Ru, Rh, Pd, Ni or Ir.

4. The catalyst of any one of claims 1 to 3 wherein the catalytic element is metallic nickel.

5. The catalyst of any one of claims 1 to 4 wherein x is between 0.01 and 0.25.

6. The catalyst of any one of claims 1 to 5 wherein x is between 0.1 and 0.2.

7. The catalyst of any one of claims 1 to 6 wherein the catalyst includes regions of metallic nickel dispersed on a surface of the substrate.

8. The catalyst of any one of claims 1 to 7 wherein the catalyst includes between 1% and 40% of the catalytic element by weight.

9. The catalyst of any one of claims 1 to 8 wherein the substrate has a specific surface area of between 10 and 300 m^2/g.

10. Use of a catalyst as described in any one of claims 1 to 9 for catalysing a methanation reaction.

11. Use of a catalyst as described in any one of claims 1 to 9, said use being for reducing the carbon monoxide content of a gas mixture including carbon monoxide and hydrogen.

12. A method for methanation of a feedstock including carbon monoxide and hydrogen, said method comprising contacting the feedstock with a catalyst as described in any one of claims 1 to 9.

13. The method of claim 12 wherein the feedstock additionally includes carbon dioxide gas.

14. The method of claim 12 or 13 wherein the feedstock additionally includes steam.

15. The method of any one of claims 12 to 14 wherein the feedstock includes coal gasification effluent and/or biomass gasification effluent.

16. The method of any one of claims 12 to 15 wherein the feedstock additionally includes a sulfur-containing gas or vapour.

17. The method of claim 16 wherein the sulfur-containing gas or vapour is present at a concentration of 0.1 to 5000 ppm.

18. The method of claim 16 or 17 wherein the sulfur-containing gas or vapour includes any one or more of hydrogen sulfide, carbonyl sulfide, sulfur dioxide and an organic thiol.

19. The method of any one of claims 12 to 18 wherein the molar ratio of hydrogen to carbon monoxide in the feedstock is between 4:1 and 1:1.

20. The method of any one of claims 12 to 19 wherein contacting includes passing the feedstock through a packed bed reactor including the catalyst.

21. The method of any one of claims 12 to 20 wherein the feedstock has a pressure during said contacting of between abot 1 bar and 40 bar.

22. The method of any one of claims 12 to 21 wherein said contacting is conducted at a temperature of at least about 250 °C, or between 250 and 750 °C.

23. The method of any one of claims 12 to 22 wherein the feedstock has a gas hourly space velocity of between 1000 h^{-1} and 100 000 h^{-1}.

24. The method of any one of claims 12 to 23 wherein the temperature and feedstock gas hourly space velocity during said contacting are sufficient to achieve equilibrium conversion of carbon oxides to methane.

25. Use of a particulate substrate of general formula $Ce_{1-x}M_xO_2$, for reducing poisoning of a catalytic element by a sulfur-containing gas or vapour, said substrate comprising: Ce and at least one metallic element (M) selected from the group consisting of Y, Gd, Sm and alkaline earth metals, and wherein x is the total proportion of M and is between 0.01 and 0.3.

26. A method for reducing poisoning of a catalytic element by a sulfur-containing gas or vapour, said method comprising: depositing said catalytic element on a particulate substrate which comprises Ce and at least one metallic element (M) selected from the group consisting of Y, Gd, Sm and alkaline earth metals; wherein said substrate has general formula $Ce_{1-x}M_xO_2$, and wherein x is the total proportion of M and is between 0.01 and 0.3.

27. The method of claim 26 wherein said depositing is conducted before exposing said catalytic element to the sulfur-containing gas or vapour.

28. The method of claim 26 or claim 27 wherein the depositing is such that the catalytic element is present in discrete regions on the substrate.