CLAIMS

1. A composite catalyst for methane cracking, the composite catalyst comprising:

a substrate formed of metal oxide; and

one or more catalytic transition metals solubilized in the metal oxide,

wherein the metal oxide comprises a metal which differs from the one or more catalytic transition metals,

wherein the metal oxide forms a matrix which the one or more catalytic transition metals are solubilized in to render transition metal ions from the one or more catalytic transition metals,

wherein the transition metal ions under a reducing atmosphere diffuse to reside as transition metal nanoparticles at a surface of the substrate and the transition metal nanoparticles under an oxidizing atmosphere diffuse away from the surface to reside as transition metal ions in the metal oxide, wherein the oxidizing atmosphere comprises:

oxygen and/or air; and

a temperature ranging from 800°C to 1400°C, and

wherein the transition metal nanoparticles at the surface induce carbon from the methane cracking to deposit on the transition metal nanoparticles and have the carbon deposited grow away from the substrate.

2. The composite catalyst of claim 1, wherein the metal oxide and the carbon deposited have different thermal expansion coefficient, which renders separation of the carbon from the substrate when the composite catalyst is cooled after being channeled out of a reactor operable to crack methane.

3. The composite catalyst of claim 1 or 2, wherein the metal oxide comprises a cobalt-based metal oxide, a nickel-based metal oxide, a chromium-based metal oxide, an iron-based metal oxide, manganese-based oxide, or a molybdenum-based metal oxide, wherein the chromium-based metal oxide comprises chromium (III) oxide or lanthanum strontium manganese chromite.

4. The composite catalyst of any one of claims 1 to 3, wherein the metal oxide has a spinel structure, a structure identical to a perovskite, or a double perovskite structure.

5. The composite catalyst of any one of claims 1 to 4, wherein the one or more catalytic transition metals comprise cobalt, nickel, chromium, iron, manganese, molybdenum, tungsten, or vanadium.

6. The composite catalyst of any one of claims 1 to 5, wherein the metal oxide comprises 50 wt% or more of the composite catalyst.

7. The composite catalyst of any one of claims 1 to 6, wherein the reducing atmosphere comprises:

hydrogen; and

a temperature ranging from 400ºC to 1000ºC.

~~8. The composite catalyst of any one of claims 1 to 7, wherein the oxidizing atmosphere comprises:~~

~~oxygen and/or air; and~~

~~a temperature ranging from 800ºC to 1400ºC.~~

~~9~~8. The composite catalyst of any one of claims 1 to ~~8~~7, wherein the composite catalyst comprises the metal oxide and one catalytic transition metal, wherein the metal of the metal oxide and the one catalytic transition metal are present in a mole ratio ranging from 5:1 to 1:5.

~~10~~9. The composite catalyst of any one of claims 1 to ~~8~~7, wherein the composite catalyst comprises $La_{0.75}Sr_{0.25}Cr_{0.5}Mn_{0.5}Ni_xO_3$, wherein x denotes a real number ranging from 0 to 3.

~~11~~10. The composite catalyst of any one of claims 1 to ~~10~~9, further comprising a sintering additive, wherein the sintering additive comprise ZrO_2, Al_2O_3, CeO_2, SiO_2, or a clay.

~~12~~11. A method of producing the composite catalyst of any one of claims 1 to ~~11~~10, the method comprising:

milling a mixture comprising transition metal oxide and a precursor of the one or more catalytic transition metals in an aqueous medium;

drying the mixture to form a homogeneously mixed powder; and

subjecting the homogenously mixed powder to calcination to produce the composite catalyst.

~~13~~12. The method of claim ~~12~~11, wherein the precursor of the one or more catalytic transition metals comprises cobalt oxide, nickel oxide, chromium oxide, iron oxide, manganese oxide, molybdenum oxide, tungsten oxide, or vanadium oxide.

~~14~~13. The method of claim ~~12~~11 or ~~13~~12, further comprising sintering the composite catalyst.

~~15~~14. The method of claim ~~14~~13, wherein the calcination and the sintering are carried out at a temperature ranging from 900ºC to 1200ºC for 6 to 24 hours and 1200ºC to 1500ºC for 2 to 10 hours, respectively.

~~16~~15. The method of claim ~~14~~13 or ~~15~~14, further comprising, prior to the sintering, milling the homogeneously mixed powder in the presence of an aqueous solution comprising at least two monomers, an initiator, a catalyst, and a dispersant.

~~17~~16. The method of claim ~~16~~15, wherein the at least two monomers comprise an acrylamide and/or N,N′-methylenebisacrylamide.

~~18~~17. The method of claim ~~16~~15 or ~~17~~16, wherein the dispersant comprises ammonium poly(methacrylate).

~~19~~18. The method of any one of claims ~~16~~15 to ~~18~~17, further comprising, after milling the homogeneously mixed powder in the presence of the aqueous solution but prior to

the calcination, mixing the homogeneously mixed powder with the initiator and the catalyst for polymerization of the at least two monomers.

~~20~~19. The method of any one of claims ~~16~~15 to ~~19~~18,
wherein the initiator comprises ammonium bisulfate,
wherein the catalyst comprises tetramethylethylenediamine.