external world. Later the synthesis of asymmetric semiconductor-metal heterostructures was effected in which gold was grown on one side of CdSe nanocrystal rods and dots. Theoretical modelling and experimental analysis show that the one-side nanocomposites are transformed from the two-sided architectures, through a repining process. Subsequently, various approaches have been developed for the synthesis of semiconductor-metal nanocomposites by anisotropic growth of metals on semiconductors through reduction, physical deposition, or photochemistry. Examples include ZnO-Ag, CdS-Au, InAs-Au, TiO_2-Co, PbS-Au, Ag_2S-Au, and semiconductor-Pt systems.

Most recently, the present inventors contributed a general protocol to transfer the transition metal ions from water to an organic medium using an ethanol mediated method, which has been extended to synthesize a wide variety of heterogeneous semiconductor-noble metal nanocomposites (J. Yang, J. Y. Ying, *Nat. Mater.* **8**, 683 (2009)). In other work, the inventors synthesized three different types of semiconductor-Au nanocomposites (CdS-Au, CdSe-Au and PbS-Au) via solution methods and tested their catalytic activities in the three-component coupling reaction of the model substrates benzaldehyde, piperidine and phenylacetylene in water. It was found that through the electronic coupling between semiconductor and Au domains, PbS-Au nanocomposites provided the highest activity, giving the desired propargylic amine product in isolated yield up to 95%.

Summary ~~of the Invention~~

In a first ~~aspect~~embodiment of the ~~invention~~disclosure there is provided nanocomposite particle comprising:

a nanoparticle, optionally a spherical nanoparticle, having a surface comprising, optionally consisting essentially of, a silver salt, optionally silver sulfide,

at least one region, optionally approximately circular, of a first noble metal on said surface, optionally on only a portion of said surface, and

optionally at least one region, optionally approximately circular, of a second noble metal on said surface, said second noble metal being different to the first noble metal,

wherein if said first noble metal is gold, there is at least one region of the second noble metal on said surface.

The first noble metal and, if present, the second noble metal, may each independently be selected from the group consisting of gold, platinum, palladium, rhodium, osmium, silver, ruthenium and iridium.

In the case where the first metal or the second metal is gold, there may be only one region of gold on the surface of each nanoparticle although in some instances there may be more than one region of gold. In the case where the first metal or the second metal is not gold, there may be more than one region of said metal on the surface of each nanoparticle, or of some nanoparticles.

In one aspect, there is provided a nanocomposite particle comprising:

a nanoparticle having a surface comprising a silver salt, and

at least one region of a first noble metal on said surface;

said nanocomposite particle additionally comprising at least one region of a second noble metal on said surface, said second noble metal being different to the first noble metal.

In ~~one~~another embodiment there is provided a nanocomposite particle comprising:

a nanoparticle having a surface comprising a silver salt, and

at least one region of a first noble metal on said surface,

wherein if said first noble metal is gold, there is additionally at least one region of a second noble metal on said surface, said second noble metal being different to the first noble metal.

In an embodiment there is provided a nanocomposite particle comprising:

a nanoparticle having a surface comprising (optionally consisting essentially of) a silver salt,

at least one region of gold on said surface, and

at least one region of a second noble metal on said surface, said second noble metal being not gold.

In another embodiment there is provided a nanocomposite particle comprising:

a nanoparticle having a surface comprising (optionally consisting essentially of) a silver salt,

at least one region of a first noble metal which is not gold on said surface.

In another embodiment there is provided a nanocomposite particle comprising:

a nanoparticle having a surface comprising (optionally consisting essentially of) a silver salt,

at least one region of a first noble metal on said surface, and

at least one region of a second noble metal on said surface,

wherein neither the first not the second noble metal is gold.

The regions of noble metal may be directly adjacent the silver salt surface. There may be no region of noble metal on another region of noble metal.

In ~~a second aspect~~another embodiment of the ~~invention~~disclosure there is provided a nanocomposite material comprising, optionally consisting essentially of, a plurality of nanocomposite particles according to the first ~~aspect~~embodiment.

The nanocomposite particles of the nanocomposite material may have a mean diameter of about 3 to about 15nm. The nanocomposite particles may be substantially monodispersed, or may have a narrow particle size distribution.

In another aspect, there is provided a nanocomposite material comprising a plurality of nanocomposite particles comprising:

a nanoparticle having a surface comprising a silver salt, and

at least one region of a first noble metal on said surface,

wherein if said first noble metal is gold, there is additionally at least one region of a second noble metal on said surface, said second noble metal being different to the first noble metal;

wherein the nanocomposite particles of the nanocomposite material have a mean diameter of about 3 to about 15nm.

In another ~~third~~ aspect, ~~of the invention~~ there is provided a process for making a nanocomposite material comprising a plurality of nanocomposite particles ~~according to the second aspect, said process~~ comprising:

a nanoparticle having a surface comprising a silver salt, and

at least one region of a first noble metal on said surface,

wherein if said first noble metal is gold, there is additionally at least one region of a second noble metal on said surface, said second noble metal being different to the first noble metal, said process comprising:

combining a heated aqueous mixture comprising nanoparticles, optionally monodispersed nanoparticles, optionally having a mean diameter between about 3 and about 15 nm, and a reducing agent such as citric acid with a compound or complex (for example a halide compound or complex) of a first noble metal, said nanoparticles each having a surface comprising, optionally consisting essentially of, a silver salt, optionally silver sulfide; and

maintaining the resulting reaction mixture at an elevated temperature for sufficient time to form at least one region, optionally approximately circular, of the first noble metal on the surface of said nanoparticles, optionally on only a portion of said surface;

thereby forming an aqueous dispersion of the nanocomposite material.

The process may additionally comprise the step combining the resulting aqueous dispersion with further reducing agent (such as citric acid) and a compound or complex

(for example a halide compound or complex) of a second noble metal, and maintaining the resulting mixture at an elevated temperature for sufficient time to form at least one region, optionally approximately circular, of the second noble metal on the surface of said nanoparticles, said second noble metal being different to the first noble metal. The further reducing agent may be the same as the original reducing agent, or may be different thereto. The elevated temperature and time for this step may be the same as for the formation of the region(s) of the first noble metal or may be different thereto. In the event that the first noble metal is gold, this step will be conducted. In the event that the first noble metal is not gold, this step is optional.

The process may additionally comprise the step of preparing the nanoparticles by a process comprising combining an aqueous solution of a water soluble silver salt, optionally silver nitrate, and a stabilising agent such as bis(p-sulfonatophenyl)phenylphosphane dihydrate dipotassium salt with an aqueous solution of a water soluble salt comprising a counterion, optionally sulfide, capable of forming an insoluble salt with silver ions, so as to form the nanoparticles in the form of an aqueous dispersion of the silver salt of the counterion.

In another aspect, there is provided a process for making a nanocomposite material comprising a plurality of nanocomposite particles comprising:

a nanoparticle having a surface comprising a silver salt, and

at least one region of a first noble metal on said surface,

wherein if said first noble metal is gold, there is additionally at least one region of a second noble metal on said surface, said second noble metal being different to the first noble metal, said process comprising:

combining a heated aqueous mixture comprising nanoparticles and a reducing agent with at least two compounds or complexes of different noble metals or with a mixed metal compound or complex comprising at least two different noble metals in the same compound or complex, said nanoparticles each having a surface comprising a silver salt; and

maintaining the resulting reaction mixture at an elevated temperature for sufficient time to form either at least one region of each noble metal or else at least one region of a mixture of the noble metals on the surface of said nanoparticles; thereby forming an aqueous dispersion of the nanocomposite material.

In an embodiment there is provided a process for making a nanocomposite material as defined above~~according to the second aspect~~, said process comprising:

combining a heated aqueous mixture comprising nanoparticles and citric acid or citrate with a halide compound or complex of a first noble metal, said nanoparticles each having a surface consisting essentially of silver sulfide; and

maintaining the resulting reaction mixture at an elevated temperature for sufficient time to form at least one region of the first noble metal on a portion of the surface of said nanoparticles;

thereby forming an aqueous dispersion of the nanocomposite material.

In another embodiment there is provided a process for making a nanocomposite material as defined above~~according to the second aspect~~, said process comprising:

combining a heated aqueous mixture comprising nanoparticles and citric acid or citrate with a halide compound or complex of gold, said nanoparticles each having a surface consisting essentially of silver sulfide;

maintaining the resulting reaction mixture at an elevated temperature for sufficient time to form at least one region of gold on a portion of the surface of said nanoparticles;

combining the resulting aqueous dispersion with further citric acid or citrate and a halide compound or complex of a second noble metal, and

maintaining the resulting mixture at an elevated temperature for sufficient time to form at least one region of the second noble metal on the surface of said nanoparticles, said second noble metal being not gold;

thereby forming an aqueous dispersion of the nanocomposite material.

In ~~a fourth aspect~~another embodiment of the ~~invention~~disclosure there is provided a process for making a nanocomposite material as defined above~~according to the second aspect~~, said process comprising:

combining a heated aqueous mixture comprising nanoparticles, optionally monodispersed nanoparticles, optionally having a mean diameter between about 3 and about 15 nm, and a reducing agent such as citric acid with at least two compounds or complexes (for example halide compounds or complexes) of different noble metals or with a mixed metal compound or complex comprising at least two different noble metals in the same compound or complex (for example halide compound or complex), said nanoparticles each having a surface comprising, optionally consisting essentially of, a silver salt, optionally silver sulfide;

maintaining the resulting reaction mixture at an elevated temperature for sufficient time to form either at least one region, optionally approximately circular, of each noble

metal or else at least one region, optionally approximately circular, of a mixture of the noble metals on the surface of said nanoparticles, optionally on only a portion of said surface;

thereby forming an aqueous dispersion of the nanocomposite material.

In an embodiment there is provided a process for making a nanocomposite material according to the second aspect, said process comprising:

combining a heated aqueous mixture comprising nanoparticles and citric acid or citrate with at least two halide compounds or complexes of different noble metals (i.e. with a halide compound or complex of a first noble metal and a halide compound or complex of a second noble metal) or with a mixed metal halide compound or complex comprising at least two different noble metals in the same compound or complex, said nanoparticles each having a surface consisting essentially of silver sulfide;

maintaining the resulting reaction mixture at an elevated temperature for sufficient time to form either at least one region of each noble metal or else at least one region of a mixture of the noble metals on a portion of the surface of said nanoparticles;

thereby forming an aqueous dispersion of the nanocomposite material

The process as defined above~~of of the third or fourth aspect~~ may additonally comprise

adding to the aqueous dispersion of the nanocomposite material a solution of an amine, preferably a C8 to C18 amine, in a water soluble organic solvent, optionally a water soluble alcohol, and

agitating the resulting mixture with a second solvent, preferably an aromatic hydrocarbon, which forms a two phase system with said mixture, so as to transfer the nanocomposite material to the second solvent and form a dispersion of the nanocomposite material in the second solvent.

In another ~~fifth~~ aspect, ~~of the invention~~ there is provided a method for adsorbing a nanocomposite material comprising a plurality of nanocomposite particles comprising:

a nanoparticle having a surface comprising a silver salt, and

at least one region of a first noble metal on said surface,

wherein if said first noble metal is gold, there is additionally at least one region of a second noble metal on said surface, said second noble metal being different to the first noble metal,~~according to the second aspect~~ onto a substrate, e.g. onto particulate carbon, said method comprising combining a dispersion, optionally a dispersion in an organic solvent such as an aromatic hydrocarbon, of said nanocomposite material in a solvent with the substrate (e.g. the particulate carbon) and agitating the resulting mixture for sufficient time to absorb the nanocomposite material onto the surface of the particulate carbon.

In another ~~sixth~~ aspect, ~~of the invention~~ there is provided an electrode comprising:

a glassy carbon electrode; and

a coating composition comprising a nanocomposite material ~~according to the second aspect~~ absorbed onto a particulate carbon, said coating composition being disposed on, optionally coupled to, the surface of the glassy carbon electrode, said nanocomposite material comprising a plurality of nanocomposite particles comprising:

a nanoparticle having a surface comprising a silver salt, and

at least one region of a first noble metal on said surface,

wherein if said first noble metal is gold, there is additionally at least one region of a second noble metal on said surface, said second noble metal being different to the first noble metal.

In another aspect, there is provided a method, comprising:

applying an electrode in a methanol reduction, said electrode comprising:

a glassy carbon electrode; and

a coating composition comprising a nanocomposite material adsorbed onto a particulate carbon, said coating composition being disposed on the surface of the glassy carbon electrode, said nanocomposite material comprising a plurality of nanocomposite particles comprising:

a nanoparticle having a surface comprising a silver salt, and

at least one region of a first noble metal on said surface,

wherein if said first noble metal is gold, there is additionally at least one region of a second noble metal on said surface, said second noble metal being different to the first noble metal.

In another aspect, there is provided an electrode comprising:

a glassy carbon electrode; and

a coating composition comprising a nanocomposite material adsorbed onto a particulate carbon, said coating composition being disposed on the surface of the glassy carbon electrode, said nanocomposite material comprising a plurality of nanocomposite particles comprising:

a nanoparticle having a surface comprising a silver salt, and

at least one region of a first noble metal on said surface,

wherein if said first noble metal is gold, there is additionally at least one region of a second noble metal on said surface, said second noble metal being different to the first noble metal, wherein at least one noble metal on the surface of nanocomposite particles of the nanocomposite material is platinum.

Detailed Description

The invention as disclosed herein is directed to nanocomposite compositions comprising silver salts, e.g. Ag_2S, and different noble metals and the synthesis of nanocomposites consisting of silver salts, e.g. Ag_2S, and different noble metals. The silver salt is commonly a silver (I) salt. By reducing various noble metal precursors using citrate in aqueous phase in the presence of previously formed nanocrystals of the silver salt, uniform semiconductor–noble metal heterogeneous nanostructures were obtained as the dominant product. In addition to the binary nanocomposites, ternary and quadruple hybrid systems were achieved by successive deposition of different noble metals on Ag_2S nanocrystals. Of these, the Pt containing nanocomposites exhibit superior catalytic activity toward the methanol oxidation, the key reaction in direct methanol fuel cell, due to the relative smaller Pt sizes and electronic coupling between semiconductor and noble metal domains.

One aspect of the invention is a nanocomposite particle comprising a nanoparticle having a surface comprising a silver salt, and at least one region of a first noble metal, and optionally at least one region of a second noble metal, wherein the second noble metal is different from the first noble metal. If the first noble metal is gold, there is at least one region of a second noble metal on the particle surface. In the event that one of the noble metals is gold, there is commonly no more than one region of gold, optionally approximately circular, on each nanoparticle. For other noble metals there may be one or more region thereof on the surface of each nanoparticle, e.g. 2, 3, 4 or 5 regions. In some embodiments the region of noble metal completely covers the entire surface of the nanoparticle. In other embodiments it (or they) only cover a portion of the surface. Each region of noble metal may cover from about 1 to about 100% of the surface area of the nanoparticle, or about 1 to 50, 1 to 20, 1 to 10, 1 to 5, 5 to 100, 10 to 100, 20 to 100, 50 to 100, 5 to 50, 5 to 20, 5 to 10, 10 to 50 or 50 to 80%, e.g. about 1, 2, 3, 4, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50, 55, 60, 65, 70, 75, 80, 85, 90, 95 or 100% of the surface of the nanoparticle. In some embodiments, the nanoparticle is essentially spherical. In some embodiments, the silver salt consists essentially of silver sulfide. In some embodiments the nanoparticles consist essentially of the silver salt, commonly silver sulfide, together with the noble metal region(s) on the surface thereof. In some embodiments the or each

Claims:

1. A nanocomposite particle comprising:

a nanoparticle having a surface comprising a silver salt, and

at least one region of a first noble metal on said surface,

wherein if said first noble metal is gold, there is additionally at least one region of a second noble metal on said surface, said second noble metal being different to the first noble metal.

2. The nanocomposite particle of claim 1 additionally comprising at least one region of a second noble metal on said surface, said second noble metal being different to the first noble metal.

3. The nanocomposite particle of claim 1 or claim 2 wherein the first noble metal and, if present, the second noble metal, are each independently selected from the group consisting of gold, platinum, palladium, rhodium, osmium, silver, ruthenium and iridium.

4. A nanocomposite material comprising a plurality of nanocomposite particles according to any one of claims 1 to 3.

5. The nanocomposite material of claim 4 wherein the nanocomposite particles of the nanocomposite material have a mean diameter of about 3 to about 15nm.

6. A process for making a nanocomposite material according to claim 4 or claim 5, said process comprising:

combining a heated aqueous mixture comprising nanoparticles and a reducing agent with a compound or complex of the first noble metal, said nanoparticles each having a surface comprising a silver salt; and

maintaining the resulting reaction mixture at an elevated temperature for sufficient time to form at least one region of the first noble metal on the surface of said nanoparticles;

thereby producing an aqueous dispersion of the nanocomposite material.

7. The process of claim 6 wherein the reducing agent comprises citric acid and/or citrate.

8. The process of claim 6 or claim 7 additionally comprising the step of combining the dispersion with further reducing agent and a compound or complex of the second noble metal, and maintaining the resulting mixture at an elevated temperature for sufficient time to form at least one region of the second noble metal on the surface of said nanoparticles, said second noble metal being different to the first noble metal;

thereby forming an aqueous dispersion of the nanocomposite material in which the nanoparticles comprise at least one region of the first noble metal and at least one region of the second noble metal on the surface thereof.

9. The process of any one of claims 6 to 8 comprising the step of preparing the nanoparticles by a combining an aqueous solution of a water soluble silver salt and a stabilising agent with an aqueous solution of a water soluble salt comprising a counterion capable of forming an insoluble salt with silver ions, so as to form the nanoparticles in the form of an aqueous dispersion of the silver salt of the counterion.

10. The process of claim 9 wherein the stabilising agent is bis(p-sulfonatophenyl)phenylphosphane dihydrate dipotassium salt.

11. A process for making a nanocomposite material according to claim 4 or claim 5, said process comprising:

combining a heated aqueous mixture comprising nanoparticles and a reducing agent with at least two compounds or complexes of different noble metals or with a mixed metal compound or complex comprising at least two different noble metals in the same compound or complex, said nanoparticles each having a surface comprising a silver salt; and

maintaining the resulting reaction mixture at an elevated temperature for sufficient time to form either at least one region of each noble metal or else at least one region of a mixture of the noble metals on the surface of said nanoparticles;

thereby forming an aqueous dispersion of the nanocomposite material.

12. The process of any one of claims 6 to 11 additionally comprising:

adding to the aqueous dispersion of the nanocomposite material a solution of an amine in a water soluble organic solvent, and

agitating the resulting mixture with a second solvent which forms a two phase system with said mixture, so as to transfer the nanocomposite material to the second solvent and form a dispersion of the nanocomposite material in the second solvent.

13. The process of any one of claims 6 to 12 wherein the silver salt is silver sulfide.

14. A method for adsorbing a nanocomposite material according to claim 4 or claim 5 onto a particulate carbon, said method comprising combining a dispersion of said nanocomposite material in a solvent with the particulate carbon and agitating the resulting mixture for sufficient time to adsorb the nanocomposite material onto the surface of the particulate carbon.

15. The method of claim 14 wherein the solvent is an aromatic hydrocarbon solvent.

16. An electrode comprising:

a glassy carbon electrode; and

a coating composition comprising a nanocomposite material according to claim 5 or claim 6 adsorbed onto a particulate carbon, said coating composition being disposed on the surface of the glassy carbon electrode.

17. The electrode of claim 16 wherein at least one noble metal on the surface of nanocomposite particles of the nanocomposite material is platinum.

18. Use of an electrode according to claim 17 in methanol reduction.

19. Use according to claim 18 wherein at least one noble metal on the surface of nanocomposite particles of the nanocomposite material is platinum.

CLAIMS

1. A nanocomposite particle comprising:

a nanoparticle having a surface comprising a silver salt, and

at least one region of a first noble metal on said surface;

said nanocomposite particle additionally comprising at least one region of a second noble metal on said surface, said second noble metal being different to the first noble metal.

2. The nanocomposite particle of claim 1 wherein the first noble metal and the second noble metal, are each independently selected from the group consisting of gold, platinum, palladium, rhodium, osmium, silver, ruthenium and iridium.

3. A nanocomposite material comprising a plurality of nanocomposite particles comprising:

a nanoparticle having a surface comprising a silver salt, and

at least one region of a first noble metal on said surface,

wherein if said first noble metal is gold, there is additionally at least one region of a second noble metal on said surface, said second noble metal being different to the first noble metal;

wherein the nanocomposite particles of the nanocomposite material have a mean diameter of about 3 to about 15nm.

4. A process for making a nanocomposite material comprising a plurality of nanocomposite particles comprising:

a nanoparticle having a surface comprising a silver salt, and

at least one region of a first noble metal on said surface,

wherein if said first noble metal is gold, there is additionally at least one region of a second noble metal on said surface, said second noble metal being different to the first noble metal, said process comprising:

combining a heated aqueous mixture comprising nanoparticles and a reducing agent with a compound or complex of the first noble metal, said nanoparticles each having a surface comprising a silver salt; and

maintaining the resulting reaction mixture at an elevated temperature for sufficient time to form at least one region of the first noble metal on the surface of said nanoparticles; thereby producing an aqueous dispersion of the nanocomposite material.

5. The process of claim 4 wherein the reducing agent comprises citric acid and/or citrate.

6. The process of claim 4 additionally comprising combining the dispersion with further reducing agent and a compound or complex of the second noble metal, and maintaining the resulting mixture at an elevated temperature for sufficient time to form at least one region of the second noble metal on the surface of said nanoparticles, said second noble metal being different to the first noble metal;
thereby forming an aqueous dispersion of the nanocomposite material in which the nanoparticles comprise at least one region of the first noble metal and at least one region of the second noble metal on the surface thereof.

7. The process of claim 4 comprising preparing the nanoparticles by a combining an aqueous solution of a water soluble silver salt and a stabilising agent with an aqueous solution of a water soluble salt comprising a counterion capable of forming an insoluble salt with silver ions, so as to form the nanoparticles in the form of an aqueous dispersion of the silver salt of the counterion.

8. The process of claim 7 wherein the stabilising agent is bis(p-sulfonatophenyl)phenylphosphane dihydrate dipotassium salt.

9. A process for making a nanocomposite material comprising a plurality of nanocomposite particles comprising:

a nanoparticle having a surface comprising a silver salt, and

at least one region of a first noble metal on said surface,

wherein if said first noble metal is gold, there is additionally at least one region of a second noble metal on said surface, said second noble metal being different to the first noble metal, said process comprising:

combining a heated aqueous mixture comprising nanoparticles and a reducing agent with at least two compounds or complexes of different noble metals or with a mixed metal compound or complex comprising at least two different noble metals in the same compound or complex, said nanoparticles each having a surface comprising a silver salt; and

maintaining the resulting reaction mixture at an elevated temperature for sufficient time to form either at least one region of each noble metal or else at least one region of a mixture of the noble metals on the surface of said nanoparticles; thereby forming an

aqueous dispersion of the nanocomposite material.

10. The process of claim 4 additionally comprising:

adding to the aqueous dispersion of the nanocomposite material a solution of an amine in a water soluble organic solvent, and

agitating the resulting mixture with a second solvent which forms a two phase system with said mixture, so as to transfer the nanocomposite material to the second solvent and form a dispersion of the nanocomposite material in the second solvent.

11. The process of claim 4 wherein the silver salt is silver sulfide.

12. A method for adsorbing a nanocomposite material comprising a plurality of nanocomposite particles comprising:

a nanoparticle having a surface comprising a silver salt, and

at least one region of a first noble metal on said surface,

wherein if said first noble metal is gold, there is additionally at least one region of a second noble metal on said surface, said second noble metal being different to the first noble metal, onto a particulate carbon, said method comprising combining a dispersion of said nanocomposite material in a solvent with the particulate carbon and agitating the resulting mixture for sufficient time to adsorb the nanocomposite material onto the surface of the particulate carbon.

13. The method of claim 12 wherein the solvent is an aromatic hydrocarbon solvent.

14. An electrode comprising:

a glassy carbon electrode; and

a coating composition comprising a nanocomposite material adsorbed onto a particulate carbon, said coating composition being disposed on the surface of the glassy carbon electrode, said nanocomposite material comprising a plurality of nanocomposite particles comprising:

a nanoparticle having a surface comprising a silver salt, and

at least one region of a first noble metal on said surface,

wherein if said first noble metal is gold, there is additionally at least one region of a second noble metal on said surface, said second noble metal being different to the first noble metal.

15. The electrode of claim 14 wherein at least one noble metal on the surface of nanocomposite particles of the nanocomposite material is platinum.

16. A method, comprising:

applying an electrode in a methanol reduction, said electrode comprising:

a glassy carbon electrode; and

a coating composition comprising a nanocomposite material adsorbed onto a particulate carbon, said coating composition being disposed on the surface of the glassy carbon electrode, said nanocomposite material comprising a plurality of nanocomposite particles comprising:

a nanoparticle having a surface comprising a silver salt, and

at least one region of a first noble metal on said surface,

wherein if said first noble metal is gold, there is additionally at least one region of a second noble metal on said surface, said second noble metal being different to the first noble metal.

17. An electrode comprising:

a glassy carbon electrode; and

a coating composition comprising a nanocomposite material adsorbed onto a particulate carbon, said coating composition being disposed on the surface of the glassy carbon electrode, said nanocomposite material comprising a plurality of nanocomposite particles comprising:

a nanoparticle having a surface comprising a silver salt, and

at least one region of a first noble metal on said surface,

wherein if said first noble metal is gold, there is additionally at least one region of a second noble metal on said surface, said second noble metal being different to the first noble metal, wherein at least one noble metal on the surface of nanocomposite particles of the nanocomposite material is platinum.