Claims

1. A method for forming noble metal nanoparticles on a support, comprising:

mixing a support ink with one or more noble metal precursor solutions, wherein the support ink comprises a solution of a first polyhydric alcohol and the support, wherein the one or more noble metal precursor solutions comprise a solution of a second polyhydric alcohol and one or more noble metal precursors;

feeding the mixture of the support ink and the one or more noble metal precursor solutions to a spiral glass tube reactor; and

heating the spiral glass tube reactor containing the mixture of the support ink and the one or more noble metal precursor solutions to reduce the one or more noble metal precursors to form noble metal nanoparticles on the support,

wherein during heating the spiral glass tube reactor, a region of the spiral glass tube reactor is selectively heated;

and wherein an average size of the noble metal nanoparticles is greater than about 1.7 nm and no more than 2 nm,

and a loading of the noble metal nanoparticles on the support is at least 40 wt%, wherein the loading is based on the total mass of the noble metal nanoparticles and the support.

2. The method according to claim 1, wherein heating comprises exposing the spiral glass tube reactor to microwave heat or millimeter waves.

3. The method according to claim 2, wherein heating comprises exposing the spiral glass tube reactor to microwave heat at 100 °C to 200 °C.

4. The method according to claim 3, wherein heating comprises exposing the spiral glass tube reactor to microwave heat at 150 °C.

5. The method according to any one of claims 1-4, wherein the one or more noble metal precursor solutions further comprise a polybasic carboxylic acid.

6. The method according to claim 5, wherein the polybasic carboxylic acid comprises citric acid, tartaric acid, malic acid, oxalic acid, or their salts.

7. The method according to claim 6, wherein the polybasic carboxylic acid comprises citric acid or a citrate of sodium or potassium.

8. The method according to any one of claims 1-7, wherein the solution of the first polyhydric alcohol and the solution of the second polyhydric alcohol are the same.

9. The method according to claim 8, wherein the first polyhydric alcohol and the second polyhydric alcohol each comprises ethylene glycol.

10. The method according to any one of claims 1-9, further comprising adding a base solution to the mixture of the support ink and the one or more noble metal precursor solutions prior to feeding the mixture to the spiral glass tube reactor.

11. The method according to claim 10, wherein the base solution comprises a hydroxide of sodium or potassium.

12. The method according to any one of claims 1-11, wherein the noble metal nanoparticles comprise nanoparticles of platinum, ruthenium, palladium, gold, silver, rhenium, rhodium, iridium, osmium, or a combination thereof.

13. The method according to claim 12, wherein the one or more noble metal precursors comprise an oxide, a halide, a nitrite, a sulphate, or a complex of platinum, ruthenium, palladium, gold, silver, rhenium, rhodium, iridium, osmium, or a combination thereof.

14. The method according to any one of claims 1-13, wherein the support comprises one or more carbon materials selected from the group consisting of carbon black, carbon nanotube, carbon fibre, graphene, graphite, and carbon mesosphere.

15. The method according to any one of claims 1-14, further comprising filtering and drying the thus-formed supported noble metal nanoparticles.

16. The method according to claim 1, wherein the loading of the noble metal nanoparticles on the support is up to about 75 wt%.