Claims

1. A composite metal organic framework encapsulating one or more populations of particles, the composite metal organic framework comprising a first population of particles and a second population of particles,

wherein the first population of particles comprise:

an outer shell region formed from a surfactant; and

an inner region comprising one or more of a nanoparticle and/or a plurality of protein molecules;

wherein the second population of particles comprise:

an outer shell region formed from a surfactant; and

an inner region comprising one or more of a nanoparticle and/or a plurality of protein molecules, and

wherein:

the first population of particles are different to the second population of particles;

a majority of said first population of particles are located within a peripheral portion of the metal organic framework; and

a majority of said second population of particles are located within a core portion of the metal organic framework.

2. The composite metal organic framework according to Claim 1, wherein:

the first population of particles are mono-dispersed within the metal organic framework; and

the second population of particles are present as particle aggregates within the metal organic framework, optionally wherein:

the interaction energy between the surfactant and the particles and/or protein molecules of the first population of particles is less than -83.7 kJ/mol (-20 kcal/mol), and

the interaction energy between the surfactant and the particles and/or protein molecules of the of the second population of particles is greater than -62.8 kJ/mol (-15 kcal/mol).

3. The composite metal organic framework according to any one of the previous Claims, wherein:

the interaction energy between the surfactant of the first population of particles and an organic linker material of the metal organic framework is greater than -41.8 kJ/mol (-10 kcal/mol), and

the interaction energy between the surfactant of the second population of particles and the organic linker material of the metal organic framework is less than -50.2 kJ/mol (-12 kcal/mol).

4. The composite metal organic framework according to any one of the previous Claims, wherein the surfactant of the first population particles, and when present the second population of particles, is independently selected from the group consisting of:

a neutral surfactant (e.g. Tween-20, Tween 40, Tween 80, Triton X-100),

a cationic surfactant (e.g. one or more of the group consisting of cetrimonium bromide, dodecyltrimethylammonium bromide, tetradecyltrimethylammonium bromide (TTAB), and cetyltrimethylammonium chloride), and

an anionic surfactant (e.g. one or more of the group consisting of sodium dodecyl sulfate (SDS), sodium hexadecyl sulfate, sodium tetradecyl sulfate (STS), diethylhexyl sodium sulfosuccinate (AOT), and taurodexycholic acid sodium salt (STDC)).

5. The composite metal organic framework according to any one of the previous Claims, wherein the weight ratio of the first population of particles to the second population of particles ranges from 1:100 to 100:1, optionally from 1:50 to 50:1, more optionally from 1:20 to 20:1, further optionally from 1:10 to 10:1, further optionally still from 1:5 to 5:1, such as from 1:3 to 3:1, for example from 1:2 to 2:1.

6. The composite metal organic framework according to Claim 1, wherein:

(a) the first population of particles comprises particles mono-dispersed within the metal organic framework, optionally wherein the interaction energy between the surfactant and the nanoparticles and/or protein molecules of the first population of particles is less than -83.7 kJ/mol (-20 kcal/mol); or

(b) the first population of particles comprises particles present as particle aggregates within the metal organic framework, optionally wherein the interaction energy between the surfactant and the particles and/or protein molecules of the first population of particles is greater than -62.8 kJ/mol (-15 kcal/mol).

7. The composite metal organic framework according to any one of the preceding Claims, wherein the first population of particles comprises a first set of quantum dots.

8. The composite metal organic framework according to Claim 7, wherein the second population of particles comprises a second set of quantum dots, optionally wherein the first and second sets of quantum dots are selected from a red quantum dot, a green quantum dot

and a blue quantum dot, optionally wherein said first set of quantum dots and second set of quantum dots are configured to emit light having different wavelengths.

9. The composite metal organic framework according to any one of Claims 1 to 6, wherein the first population of particles comprises nanoparticles selected from one or more of the group consisting of an Au nanoparticle (e.g. Au nanosphere, an Au nanorod), a Fe_3O_4 nanoparticle (e.g. an Fe_3O_4 nanocube, an Fe_3O_4 nanosphere), an Ag nanoparticle (e.g. Ag nanosphere), and a CeO_2 nanoparticle (e.g. CeO_2 nanosphere),

optionally wherein the first population of particles comprises nanoparticles selected from one or more of the group consisting of an Au nanoparticle (e.g. Au nanosphere, an Au nanorod), and a Fe_3O_4 nanoparticle (e.g. an Fe_3O_4 nanocube, an Fe_3O_4 nanosphere).

10. A method of making a composite metal organic framework encapsulating a first population of particles, said method comprising the steps:

(a) providing a first population of particles, a metal node material and an organic linker material;

(b) reacting said first population of particles, metal node material and organic linker material in aqueous solution to form a composite metal organic framework where the first population of particles are entrapped by the metal organic framework,

wherein said metal node material and organic linker material are compatible to react together to form a metal organic framework, and

the first population of particles comprise:

an outer shell region formed from a surfactant; and

an inner region comprising one or more of a nanoparticle and/or a plurality of protein molecules, the method further comprising

providing a second population of particles in step (a), and reacting the second population of particles with the first population of particles, metal node material and organic linker material in aqueous solution in step (b), wherein the second population of particles comprise: an outer shell region formed from a surfactant; and an inner region comprising one or more of a nanoparticle and/or a plurality of protein molecules

wherein:

the first population of particles are different to the second population of particles;

a majority of said first population of particles are located within a peripheral portion of the metal organic framework; and

a majority of said second population of particles are located within a core portion of the metal organic framework.

11. The method according to Claim 10, further comprising the preliminary steps:

(1) determining the desired distribution and dispersion of each population of particles within the resulting composite metal organic framework; and

(2) for each population of particles, selecting the surfactant, the nanoparticle or protein molecule, the metal node material and the organic linker material compatible to form the desired metal organic framework such that:

(A) if a majority of said population of particles is desired to exist as mono-dispersed particles, selecting the surfactant and the particle and/or protein molecule such that the interaction energy between the surfactant and the particles and/or protein molecules of said population of particles is less than -83.7 kJ/mol (-20 kcal/mol),

(B) if a majority of said population of particles is desired to exist as particle aggregates, selecting the surfactant and the particles and/or protein molecules such that the interaction energy between the surfactant and the particles and/or protein molecules of said population of surfactant-coated nanoparticles is greater than -62.8 kJ/mol (-15 kcal/mol),

(C) if a majority of said population of particles is desired to be located in the periphery of the metal organic framework, selecting the surfactant, metal node material and organic linker material compatible to form the desired metal organic framework such that the interaction energy between the surfactant of said population of particles and the organic linker material of the metal organic framework is greater than -41.8 kJ/mol (-10 kcal/mol), and

(D) if a majority of said population of particles is desired to be located in the core of the metal organic framework, selecting the surfactant, metal node material and organic linker material compatible to form the desired metal organic framework such that the interaction energy between the surfactant of said population of particles and the organic linker material of the metal organic framework is less than -50.2 kJ/mol (-12 kcal/mol).

12. A method of selecting materials for forming a composite metal organic framework,

said composite metal organic framework encapsulating one or more populations of particles, where each population of particles comprises:

an outer shell region formed from a surfactant; and

an inner region comprising one or more of a nanoparticle and/or a plurality of protein molecules,

said method comprising:

(1) determining the desired distribution and dispersion of each population of particles within the resulting composite metal organic framework; and

(2) for each population of particles, selecting the surfactant, the nanoparticle or protein molecule, and a metal node material and organic linker material compatible to form the desired metal organic framework such that:

(A) if a majority of said population of particles is desired to exist as mono-dispersed particles, selecting the surfactant and the particle and/or protein molecule such that the interaction energy between the surfactant and the particles and/or protein molecules of said population of particles is less than -83.7 kJ/mol (-20 kcal/mol),

(B) if a majority of said population of particles is desired to exist as particle aggregates, selecting the surfactant and the particles and/or protein molecules such that the interaction energy between the surfactant and the particles and/or protein molecules of said population of surfactant-coated nanoparticles is greater than -62.8 kJ/mol (-15 kcal/mol),

(C) if a majority of said population of particles is desired to be located in the periphery of the metal organic framework, selecting the surfactant, metal node material and organic linker material compatible to form the desired metal organic framework such that the interaction energy between the surfactant of said population of particles and the organic linker material of the metal organic framework is greater than -41.8 kJ/mol (-10 kcal/mol), and

(D) if a majority of said population of particles is desired to be located in the core of the metal organic framework, selecting the surfactant, metal node material and organic linker material compatible to form the desired metal organic framework such that the interaction energy between the surfactant of said population of particles and the organic linker material of the metal organic framework is less than -50.2 kJ/mol (-12 kcal/mol).

13. Use of a composite metal organic framework as defined in any one of Claims 1 to 9:

(a) as a probe; or

(b) as a catalyst; or

(c) in encryption; or

(d) in fingerprint detection; or

(e) in a therapeutic delivery system.

14. A composite metal organic framework as defined in Claim 8 for use in a method of diagnosis, wherein said method of diagnosis comprises:

(a) contacting the composite metal organic framework with a biological sample;

(b) measuring the photoluminescence of the first and second set of quantum dots;

(c) determining the presence or absence of a biological marker indicated in a disease state by comparing the photoluminescence of the first and second set of quantum dots with each other or with a reference value, where said biological marker, if present, is able to selectively quench fluorescence of the first or second set of quantum dots; and

(d) assigning the presence or absence of a disease state based on the presence or absence of said biological marker.

15. A composite metal organic framework according to any one of Claims 1 to 6, wherein the nanoparticle is doxorubicin and/or the protein molecule is bovine serum albumin (BSA).

16. A composite product comprising:

a substrate; and

a composite metal organic framework according to any one of Claims 1 to 9, wherein the composite metal organic framework is coated over the whole or part of the surface of said substrate, optionally wherein the substrate is selected from the group consisting of polystyrene beads, cellulose fibre, copper wire and a glass slide.

17. A pharmaceutical composition comprising a composite metal organic framework according to Claim 1, wherein the inner region of the first population of particles comprises:

a nanoparticle comprising a small molecule active agent; and/or

a plurality of protein molecules.