Summary

In one aspect of the present disclosure, there is provided a hybrid nanodot made by a process comprising a step of reacting a mixture of poly(ethylene imine) (PEI) and an amino acid selected from the group consisting of serine, threonine, cysteine, tyrosine, asparagine, glutamine, lysine, aspartic acid, glutamic acid and mixtures thereof, under hydrothermal reaction conditions, wherein the weight ratio of amino acid to PEI is about 3:1 to about 1:1, and wherein PEI has an average molecular weight of about 1200 g/mol to about 1800 g/mol determined by light scattering.

In another aspect of the present disclosure, there is provided a process for producing a hybrid nanoparticle disclosed herein, comprising the process steps of:

(a) dissolving the amino acid and PEI in an aqueous medium;

(b) heating the obtained solution at elevated temperature and increased pressure; and

(c) separating the hybrid nanoparticles that have formed from the reaction mixture.

In a further aspect of the present disclosure, there is provided a hybrid nanodot disclosed herein for combating bacteria.

In another aspect of the present disclosure, there is provided an antimicrobial composition comprising a hybrid nanodots disclosed herein, optionally together with customary solvents, additives or fillers.

In a further aspect of the present disclosure, there is provided a use of the antimicrobial composition of disclosed herein to combat gram-positive and/or gram-negative bacteria in hygiene applications, preferably surface disinfection.

In one example of the present disclosure, there is provided a hybrid nanodot made by a process comprising a step of reacting a mixture of an amino acid and a polymer selected from polycationic polymers or any copolymers or derivatives of these polymers under hydrothermal reaction conditions.

Advantageously, the hybrid nanodots of the present disclosure may possess tunable photoluminescent, antimicrobial and bacteria-staining properties. Further advantageously, the hybrid nanodots of the present disclosure may be able to disrupt bacterial membrane, release intracellular proteins, thus allowing for potent antibacterial effects. The antibacterial effects of the hybrid nanodots of the present disclosure may be towards broad-spectrum bacteria (both gram-positive and gram-negative) and they may be advantageously effective against multidrug-resistant superbugs, such as *Pseudomonas aeruginosa*.

Also advantageously, the hybrid nanodots of the present disclosure may have small sizes and spherical shapes which may lead to fast interaction between the hybrid nandot and bacteria, which may thus achieve bacterial inhibition almost instantaneously.

Claims

1. A hybrid nanodot made by a process comprising a step of reacting a mixture of poly(ethylene imine) (PEI) and an amino acid selected from the group consisting of serine, threonine, cysteine, tyrosine, asparagine, glutamine, lysine, aspartic acid, glutamic acid and mixtures thereof, under hydrothermal reaction conditions, wherein the weight ratio of amino acid to PEI is about 3:1 to about 1:1, and wherein PEI has an average molecular weight of about 1200 g/mol to about 1800 g/mol determined by light scattering.

2. The hybrid nanodot of claim 1, wherein the PEI has an average molecular weight of about 1800 g/mol determined by light scattering.

3. The hybrid nanodot of claim 1 or 2, wherein the amino acid is selected from the group consisting of serine, threonine, and lysine.

4. The hybrid nanodot of any one of claims 1 to 3, wherein the weight ratio of amino acid to PEI is 3:1 to 1.25:1, or 2.5:1 to 1.5:1.

5. The hybrid nanodot of any one of claims 1 to 4, wherein the particle size of the hybrid nanodot is about 1 to 100 nm, preferably 2 to 50 nm, more preferably 5 to 40 nm and most preferably 7 to 20 nm.

6. The hybrid nanodot of any of claims 1 to 5, wherein the nanodots exhibit excitation-dependent fluorescence emission.

7. The hybrid nanodot of any one of claims 1 to 6 for fluorescence-based imaging of cells, preferably bacteria.

8. The hybrid nanodot of any one of claims 1 to 7, which substantially consists of a hydrophobic sp^2 carbon network with hydrophilic functional groups on the surface.

9. A process for producing a hybrid nanoparticle according to any one of claims 1 to 8, comprising the process steps of:

   (a) dissolving the amino acid and PEI in an aqueous medium;

   (b) heating the obtained solution at elevated temperature and increased pressure; and

   (c) separating the hybrid nanoparticles that have formed from the reaction mixture.

10. The process of claim 9, wherein the temperature of step (b) is between about 120 to 250 °C, preferably 150 to 210 °C and more preferably 170 to 190 °C.

11. The process according to claim 9 or 10, wherein the increased pressure in step (b) is achieved by hydrothermal reaction in an autoclave.

12. The process according to any one of claims 9 to 11, wherein the reaction in step (b) is run for 1 to 48 hours, preferably 2 to 36 hours, more preferably 20 to 30 hours and most preferably about 23 to 25 hours.

13. The process according to any one of claims 9 to 12, wherein the separation step (c) comprises one, several or all of the following steps:

    (a) centrifugation to remove precipitate;

    (b) filtration to remove precipitate;

    (c) dialysis with a given weight cut off against purified water, preferably a weight cut off of about 3,000 g/mol; and

    (d) lyophilizing and re-suspending the obtained product in ultrapure water.

14. A hybrid nanodot according to any of claims 1 to 8 for combating bacteria.

15. An antimicrobial composition comprising a hybrid nanodots according to any of claims 1 to 8, optionally together with customary solvents, additives or fillers.

16. The antimicrobial composition according to claim 15, wherein the hybrid nanodots are dispersed in an aqueous medium at a concentration of at least about 50 µg/mL, preferably of about 100 µg/mL to 10 mg/L, more preferably 150 µg/mL to 1 mg/L.

17. Use of the antimicrobial composition of claim 16 to combat gram-positive and/or gram-negative bacteria in hygiene applications, preferably surface disinfection.