formed skin layer. However, under the Acticoat™ series, only Acticoat™ Absorbent is minimally adhesive as its main function is to absorb exudate which allows gel formation and prevents attachment to newly formed skin layer. However, not all wounds release sufficient amount of exudate.

Other criteria that wound therapy agents should preferably possess is the ability to attract growth factors to the site of injury to spur cell regeneration, being flexible to facilitate application of therapeutics over awkward positions, having water proof feature and can be synthesised at low cost.

There is therefore a need to provide biomaterials that overcome, or at least ameliorate, one or more of the disadvantages described above.

Summary

According to the ~~present disclosure this object is solved by~~ first aspect, there is provided a nanoparticle-containing hydrogel comprising:

metal nanoparticles, and

at least one peptide having the general formula:

$$Z\text{-}(X)_a\text{-}(Y)_b\text{-}Z'_c$$

wherein

Z is an N-terminal protecting group;

X is, at each occurrence, independently selected from the group consisting of aliphatic amino acids and aliphatic amino acid derivatives;

Y is, at each occurrence, independently selected from the group consisting of polar amino acids and polar amino acid derivatives;

Z' is a C-terminal protecting group;

a is an integer selected from 1 to 6, preferably 1 to 5;

b is 0, 1 or 2, preferably 1; and

c is 0 or 1.

Advantageously, the peptide(s) may be able to self-assemble in water or physiologically relevant buffers to form hydrogels.

Further advantageously, the hydrogels may display superior mechanical strength. The metal nanoparticles may stabilize the fibrous structure of the hydrogel, therefore requiring a reduced concentration of peptide(s), which are considerably more expensive. Therefore advantageously, the disclosed hydrogels may be cost-effective.

According to ~~the present invention this object is solved by~~ another aspect, there is provided an *in situ* method of producing the disclosed nanoparticle-containing hydrogel, said method comprising the steps of:

(a) dissolving at least one disclosed peptide in an aqueous solution;

(b) adding a precursor of metal nanoparticles, preferably a metal salt solution;

(c) gel formation to obtain a peptide hydrogel;

(d) irradiating the peptide hydrogel resulting from step (c); and

(e) obtaining a nanoparticle-containing hydrogel.

According to ~~the present disclosure this object is solved by~~ another aspect, there is provided a nanoparticle-containing hydrogel prepared by the disclosed *in situ* method.

According to ~~the present disclosure this object is solved by~~ another aspect, there is provided ~~using~~ the use of the disclosed nanoparticle-containing hydrogel:

- as a device for metal delivery, preferably for sustained or controlled release metal delivery;
- as an antimicrobial agent;
- in a method of treatment of an infectious disease,

  wherein, preferably, said infectious disease is caused by Gram-positive bacteria, Gram-negative bacteria, yeast or fungi;
- as a wound dressing and for wound healing;
- in a surgical application;
- to prevent bacterial attachment and/or formation of microbial biofilm;
- for topical medical application;
- for bioimaging (by utilitzing the fluorescence of the metal nanoparticles);
- in combination with medical devices, such as stents, prostheses, catheters, dental implants, orthopedical devices, orthopedical implants;
- for application where the hydrogel is used as a (dried) membrane, such as filtration.

Advantageously, the disclosed hydrogels may not require additional chemical modification to display antibacterial and/or antimicrobial properties.

According to another aspect, there is provided ~~the present disclosure this object is solved by~~ a device for metal delivery, preferably sustained or controlled release metal delivery, comprising a disclosed nanoparticle-containing hydrogel.

Advantageously, the disclosed hydrogels may display sustained release of the metal nanoparticles over a long period, for example, more than 10 days.

Further advantageously, the disclosed hydrogels may be able to fully release the metal nanoparticles, even while using a low concentration of metal salt precursor.

Also advantageously, the disclosed hydrogels may only require low concentrations of metal salt precursor, which may be toxic in high amounts.

According to ~~the present disclosure this object is solved by~~ another aspect, there is provided an antimicrobial agent comprising a disclosed nanoparticle-containing hydrogel.

According to ~~the present disclosure this object is solved by~~ another aspect, there is provided a wound dressing or wound healing agent comprising a disclosed nanoparticle-containing hydrogel, which is preferably used to prevent microbial infection and/or formation of microbial biofilm.

Advantageously, the disclosed hydrogels may be able to prevent bacterial attachment, and therefore prevent the formation of biofilm.

Advantageously, the disclosed hydrogels may be able to entrap up to 99.9% water. Therefore advantageously, the moisture from the disclosed hydrogels may prevent unwanted adhesion when applied to wound sites, facilitating non-traumatic removal of the dressing. The disclosed hydrogels offer great potential for application in wound healing, in particular after surgery, in treatment of chronic and large surface wounds, like diabetic ulcer or severe burns, due to its potential to reduce inflammation and its ease of application.

According to ~~the present disclosure this object is solved by~~ another aspect, there is provided a pharmaceutical or cosmetic composition comprising a disclosed nanoparticle-containing hydrogel.

According to the present disclosure this object is solved by a method of treatment of an infectious disease, said method comprising the step of administering an effective amount of a disclosed nanoparticle-containing hydrogel or a disclosed pharmaceutical composition to a person or subject in need thereof, wherein, preferably, said infectious disease is caused by Gram-positive bacteria, Gram-negative bacteria, yeast or fungi.

According to another aspect, there is provided a disclosed nanoparticle-containing hydrogel or a disclosed pharmaceutical composition for use in the

treatment of an infectious disease wherein, preferably, said infectious disease is caused by Gram-positive bacteria, Gram-negative bacteria, yeast or fungi.

According to the present disclosure this object is solved by a method of treatment of a wound and for wound healing, said method comprising the step of applying an effective amount of a disclosed nanoparticle-containing hydrogel or a disclosed pharmaceutical composition to a wound.

According to another aspect, there is provided a disclosed nanoparticle-containing hydrogel or a disclosed pharmaceutical composition for use in the treatment of a wound and/or for wound healing.

Advantageously, the disclosed hydrogels may be flexible and therefore may be able to be applied across awkward or non-flat positions on the skin.

According to another aspect, there is provided ~~the present disclosure this object is solved by~~ a bioimaging device comprising a disclosed nanoparticle-containing hydrogel for *in vitro* and/or *in vivo* use, preferably for oral application, for injection and/or for topical application.

According to another aspect, there is provided ~~the present disclosure this object is solved by~~ the use of a disclosed nanoparticle-containing hydrogel for the manufacture of a medicament for the treatment of an infectious disease.

According to another aspect, there is provided ~~the present disclosure this object is solved by~~ the use of a disclosed nanoparticle-containing hydrogel for the manufacture of a medicament for the treatment of a wound and/or for wound healing.

According to another aspect, there is provided ~~the present disclosure this object is solved by~~ a kit, comprising

(i) at least one peptide as defined herein,
optionally, in an aqueous solution;

(ii) a precursor of metal nanoparticles,
preferably a metal salt solution (such as $AgNO_3$);

(iii) instructions for gel formation to obtain a peptide hydrogel and for irradiating the peptide hydrogel resulting therefrom for obtaining a nanoparticle-containing hydrogel;

(iv) optionally, excipients.

According to another aspect, there is provided ~~the present disclosure this object is solved by~~ a kit, comprising

(i) a hydrogel obtained from at least one peptide as defined herein,
preferably in a container to be protected from radiation;

(ii) a precursor of metal nanoparticles,
preferably a metal salt solution (such as $AgNO_3$);

(iii) instructions for irradiating the peptide hydrogel for obtaining a nanoparticle-containing hydrogel;

(iv) optionally, excipients.

Definitions

The following are some definitions that may be helpful in understanding the description of the present invention. These are intended as general definitions and

39. The pharmaceutical or cosmetic composition of claim 37, wherein the pharmaceutical or cosmetic composition is provided in the form of an injectable solution.

40. The pharmaceutical or cosmetic composition of any one of claims 37 to 39, further comprising a pharmaceutically active compound and/or a pharmaceutically acceptable carrier.

41. A ~~method of treatment of an infectious disease, said method comprising the step of~~

~~administering an effective amount of a~~ nanoparticle-containing hydrogel of any one of claims 1 to 24 and 32 or a pharmaceutical composition of any one of claims 37 to 39 for use in the treatment of an infectious disease ~~to a person or subject in need thereof,~~

wherein, preferably, said infectious disease is caused by Gram-positive bacteria, Gram-negative bacteria, yeast or fungi.

42. A ~~method of treatment of a wound and for wound healing, said method comprising the step of~~

~~applying an effective amount of a~~ nanoparticle-containing hydrogel of any one of claims 1 to 24 and 32 or a pharmaceutical composition of any one of claims 37 to 39 for use in the treatment ~~to~~of a wound and/or for wound healing.

43. A bioimaging device comprising a nanoparticle-containing hydrogel of any one of claims 1 to 24 and 32 for *in vitro* and/or *in vivo* use,

preferably for oral application, for injection and/or for topical application.

44. Use of a nanoparticle-containing hydrogel of any one of claims 1 to 24 and 32 for the manufacture of a medicament for the treatment of an infectious disease.

45. Use of a nanoparticle-containing hydrogel of any one of claims 1 to 24 and 32 for the manufacture of a medicament for the treatment of a wound and/or for wound healing.