Claims

1. A hydrogel for wound healing comprising:

a hydrogel polymeric matrix comprising:

a first polymeric component;

a second polymeric component, where the first and second polymeric components are crosslinked together to form the hydrogel polymeric matrix; and

a first portion of a polymeric antimicrobial material capable of crosslinking with the first and/or second polymeric components, said first portion being wholly or partly crosslinked into the hydrogel polymeric matrix;

a second portion of the polymeric antimicrobial material capable of crosslinking with the first and/or second polymeric components, said second portion being distributed within the hydrogel polymeric matrix but not crosslinked into the hydrogel polymeric matrix;

wherein the first and second polymeric components are selected from one of the following sets:

(a) the first polymeric component is derived from a polymeric material comprising at least two thiol functional groups and the second polymeric component is derived from a polymeric material comprising at least two maleimide groups;

(b) the first polymeric component is derived from a polymeric material comprising at least two thiol functional groups and the second polymeric component is derived from a polymeric material comprising at least two vinyl sulfone groups;

(c) the first polymeric component is derived from a polymeric material comprising at least two azide functional groups and the second polymeric component is derived from a polymeric material comprising at least two cyclooctynyl groups;

(d) the first polymeric component is derived from a polymeric material comprising at least two amine functional groups and the second polymeric component is derived from a polymeric material comprising at least two aldehyde groups; and

(e) the first polymeric component is derived from a polymeric material comprising at least two amine functional groups and the second polymeric component is derived from a polymeric material comprising at least two acrylate groups; and

optionally, an antioxidant material distributed within the hydrogel polymeric matrix and/or covalently bonded thereto.

2. The hydrogel according to Claim 1, wherein the first polymeric component is derived from a polymeric material comprising at least two thiol functional groups and the second polymeric component is derived from a polymeric material comprising at least two maleimide groups.

3. The hydrogel according to Claim 2, wherein the first polymeric component is derived from a polymeric material that has from 2 to 8 thiol functional groups and the second polymeric component is derived from a polymeric material that has from 2 to 8 maleimide groups.

4. The hydrogel according to Claim 3, wherein the first polymeric component is derived from a multi-arm polyethylene glycol having from 2 to 8 arms that are each terminated by a thiol functional group and the second polymeric component is derived from a multi-arm polyethylene glycol having from 2 to 8 arms that are each terminated by a maleimide group.

5. The hydrogel according to Claim 4, wherein the first polymeric component is derived from poly(ethylene glycol) tetra thiol and the second polymeric component is derived from poly(ethylene glycol) tetra maleimide.

6. The hydrogel according to any one of the preceding claims, wherein the polymeric antimicrobial material capable of crosslinking with the first and/or second polymeric components is selected from one or more of a polycationic polymer terminated by at least two maleimide groups, a polycationic polymer terminated by at least one maleimide group and at least one thiol group, a polycationic polymer terminated by at least two vinyl sulfone groups, a polycationic polymer terminated by at least one vinyl sulfone group and at least one thiol group, a polycationic polymer terminated by at least two cyclooctynyl groups, a polycationic polymer terminated by at least two azide groups, a polycationic polymer terminated by at least one cyclooctynyl group and at least one azide group, a polycationic polymer terminated by at least two amino groups, a polycationic polymer terminated by at least two aldehyde groups, a polycationic polymer terminated by at least one amino group and at least one aldehyde group, a polycationic polymer terminated by at least two acrylate groups, and a polycationic polymer terminated by at least one amino group and at least one acrylate group provided that said material is capable of forming a crosslink with at least one of the first and second polymeric components.

7. The hydrogel according to Claim 6, wherein the polymeric antimicrobial material is a polycationic polymer terminated by at least two maleimide groups, optionally wherein the polycationic polymer is terminated by two maleimide groups.

8. The hydrogel according to Claim 7, wherein the polymeric antimicrobial material is a polyimidazolium polymer terminated by two maleimide groups.

9. The hydrogel according to any one of the preceding claims, wherein the polymeric antimicrobial material capable of crosslinking with the first and/or second polymeric components has a number average molecular weight of from 500 Daltons to 50,000 Daltons.

10. The hydrogel according to Claim 9, wherein the polymeric antimicrobial material has a number average molecular weight of from 1,000 Daltons to 15,000 Daltons.

11. The hydrogel according to Claim 10, wherein the polymeric antimicrobial material has a number average molecular weight of from 2,000 Daltons to 10,000 Daltons, optionally wherein the polymeric antimicrobial material has a number average molecular weight of about 2,766 Daltons.

12. The hydrogel according to any one of the preceding claims, wherein the antioxidant material is present, optionally wherein the antioxidant material is N-acetyl cysteine.

13. The hydrogel according to any one of the preceding claims, wherein the hydrogel is in a form selected from a film, nanoparticles and microparticles.

14. A composite material comprising a substrate and a coating formed of a hydrogel as described in any one of Claims 1 to 13, optionally wherein the substrate is a foam.

15. A kit of parts selected from:

(i)

(ia) a first mixture comprising a first polymer capable of crosslinking with a second polymer and, optionally, an antioxidant material as described in any one of Claims 1 to 13;

(ib) a second mixture comprising a second polymer and a polymeric antimicrobial material capable of crosslinking with the first polymer; and

(ic) a pharmaceutically acceptable solvent;

or

(ii) (iia) a first mixture comprising a first polymer capable of crosslinking with a second polymer, and a polymeric antimicrobial material capable of crosslinking with the second polymer, and, optionally, an antioxidant material as described in any one of Claims 1 to 13;

(iib) a second mixture comprising a second polymer; and

(iic) a pharmaceutically acceptable solvent;

or

(iii) (iiia) a first mixture comprising a first polymer capable of crosslinking with a second polymer and a polymeric antimicrobial material capable of crosslinking with the second polymer;

(iiib) a second mixture comprising a second polymer and, optionally, an antioxidant material as described in any one of Claims 1 to 13; and

(iiic) a pharmaceutically acceptable solvent;

or

(iv) (iva) a first mixture comprising a first polymer capable of crosslinking with a second polymer and, optionally, an antioxidant material as described in any one of Claims 1 to 13;

(ivb) a second mixture comprising a second polymer;

(ivc) a pharmaceutically acceptable solvent; and

(ivd) a polymeric antimicrobial material capable of crosslinking with the first and second polymers,

wherein the first and second polymers are selected from one of the following sets:

(aa) the first polymer is a polymeric material comprising at least two thiol functional groups and the second polymer is a polymeric material comprising at least two maleimide groups;

(bb) the first polymer is a polymeric material comprising at least two thiol functional groups and the second polymer is a polymeric material comprising at least two vinyl sulfone groups;

(cc) the first polymer is a polymeric material comprising at least two azide functional groups and the second polymer is a polymeric material comprising at least two cyclooctynyl groups;

(dd) the first polymer is a polymeric material comprising at least two amine functional groups and the second polymer is a polymeric material comprising at least two aldehyde groups; and

(ee) the first polymer is a polymeric material comprising at least two amine functional groups and the second polymer is a polymeric material comprising at least two acrylate groups.

16. A method of forming a hydrogel according to any one of Claims 1 to 13, comprising the steps of:

(AA) providing at least two separate solutions, each of said solutions containing a solvent, where each of the at least two solutions contain one or more of a first polymer capable of crosslinking with a second polymer, a second polymer capable of crosslinking with the first polymer, a polymeric antimicrobial material capable of crosslinking with the first and/or second

polymer, and, optionally, an antioxidant material as described in any one of Claims 1 to 13, provided that materials that can react together are not contained in the same solution; and

(BB) mixing the at least two solutions together to form the hydrogel according to any one of Claims 1 to 13,

wherein the first and second polymers are selected from one of the following sets:

(aa) the first polymer is a polymeric material comprising at least two thiol functional groups and the second polymer is a polymeric material comprising at least two maleimide groups;

(bb) the first polymer is a polymeric material comprising at least two thiol functional groups and the second polymer is a polymeric material comprising at least two vinyl sulfone groups;

(cc) the first polymer is a polymeric material comprising at least two azide functional groups and the second polymer is a polymeric material comprising at least two cyclooctynyl groups;

(dd) the first polymer is a polymeric material comprising at least two amine functional groups and the second polymer is a polymeric material comprising at least two aldehyde groups; and

(ee) the first polymer is a polymeric material comprising at least two amine functional groups and the second polymer is a polymeric material comprising at least two acrylate groups.

17. The kit of parts according to Claim 15 or the method according to Claim 16, wherein one or more of the following apply:

(A) the first polymer is a polymeric material comprising at least two thiol functional groups and the second polymer is a polymeric material comprising at least two maleimide groups, optionally wherein:

(ff) the first polymer is a polymeric material that has from 2 to 8 thiol functional groups and the second polymer is a polymeric material that has from 2 to 8 maleimide groups;

(gg) the first polymer is a multi-arm polyethylene glycol having from 2 to 8 arms that are each terminated by a thiol functional group and the second polymer is a multi-arm polyethylene glycol having from 2 to 8 arms that are each terminated by a maleimide group;

(hh) the first polymer is poly(ethylene glycol) tetra thiol and the second polymer is poly(ethylene glycol) tetra maleimide;

(B) the polymeric antimicrobial material capable of crosslinking with the first and/or second polymers is selected from one or more of a polycationic polymer terminated by at least two

maleimide groups, a polycationic polymer terminated by at least one maleimide group and at least one thiol group, a polycationic polymer terminated by at least two vinyl sulfone groups, a polycationic polymer terminated by at least one vinyl sulfone group and at least one thiol group, a polycationic polymer terminated by at least two cyclooctynyl groups, a polycationic polymer terminated by at least two azide groups, a polycationic polymer terminated by at least one cyclooctynyl group and at least one azide group, a polycationic polymer terminated by at least two amino groups, a polycationic polymer terminated by at least two aldehyde groups, a polycationic polymer terminated by at least one amino group and at least one aldehyde group, a polycationic polymer terminated by at least two acrylate groups, and a polycationic polymer terminated by at least one amino group and at least one acrylate group provided that said material is capable of forming a crosslink with at least one of the first and second polymers, optionally wherein:

(ii) the polymeric antimicrobial material is a polycationic polymer terminated by at least two maleimide groups, optionally wherein the polycationic polymer is terminated by two maleimide groups;

(jj) the polymeric antimicrobial material is a polyimidazolium polymer terminated by two maleimide groups;

(C) the polymeric antimicrobial material capable of crosslinking with the first and/or second polymers has a number average molecular weight of from 500 Daltons to 50,000 Daltons, optionally wherein:

(kk) the polymeric antimicrobial material has a number average molecular weight of from 500 Daltons to 50,000 Daltons;

(ll) the polymeric antimicrobial material has a number average molecular weight of from 1,000 Daltons to 15,000 Daltons;

(mm) the polymeric antimicrobial material has a number average molecular weight of from 2,000 Daltons to 10,000 Daltons;

(nn) the polymeric antimicrobial material has a number average molecular weight of about 2,766 Daltons.

18. Use of a hydrogel according to any one of Claims 1 to 13 in the manufacture of a medicament for wound healing.