as layer-by-layer deposition that are suitable for laboratory research but not practical when the process is scaled up.

There is therefore a need to provide an antimicrobial coating that overcomes or at least ameliorates, one or more of the disadvantages described above.

Summary

There is provided a polymer having a plurality of pendant groups, wherein the pendant groups comprise: a first pendant group comprising a quaternary ammonium component having the following formula: $-R^1-(CH_2)_n-[N^+(R^2)(R^3)(R^4)](X^-)$; wherein n is any integer from 1 to 18; R^1 is C(O)O or C(O)NH; R^2, R^3 and R^4 are each independently an optionally substituted alkyl, optionally substituted aryl, or R^2 and $R^3$are taken together to form a ring and R^4 is H or absent; and X is selected from the group consisting of Cl, Br, I and OSO_3CH_3; and a second pendant group comprising an organosilane component, provided that there are no other pendant groups in the polymer.

In an aspect, there is provided an antimicrobial coating composition comprising a polymer having a plurality of pendant groups, wherein the pendant groups comprise: a first pendant group comprising a quaternary ammonium component having the following formula: $-R^1-(CH_2)_n-[N^+(R^2)(R^3)(R^4)](X^-)$; wherein n is any integer from 1 to 18; R^1 is C(O)O or C(O)NH; R^2 and R^3 are each independently an optionally substituted alkyl or optionally substituted aryl and R^4 is an optionally substituted C_{14} to C_{24} alkyl, or R^2 and $R^3$are taken together to form a ring and R^4 is H or absent; X is selected from the group consisting of Cl, Br, I and OSO_3CH_3; and a second pendant group comprising an organosilane component, wherein the first pendant group is derived from a first monomer comprising the quaternary ammonium component, and the second pendant group is derived from a second monomer comprising the organosilane component, wherein the ratio of the first monomer comprising the quaternary ammonium component to the second monomer comprising the organosilane component is in the range of about 100:1 to 4:1 by weight, provided that the polymer is free of any other pendant groups.

There is provided a polymer having a plurality of pendant groups, wherein the pendant groups consists of: a first pendant group comprising a quaternary ammonium component having the following formula: $-R^1-(CH_2)_n-[N^+(R^2)(R^3)(R^4)](X^-)$ wherein n is any integer from 1 to 18; R^1 is C(O)O or C(O)NH; R^2, R^3 and R^4 are each independently an optionally substituted alkyl, optionally substituted aryl, or R^2 and R^3 are taken together to form a ring and R^4 is H or absent; and X is selected from the group consisting of Cl, Br, I and OSO_3CH_3; and a second pendant group comprising an organosilane component.

In another aspect, there is provided an antimicrobial coating composition comprising a polymer having a plurality of pendant groups, wherein the pendant groups consists of: a first pendant group comprising a quaternary ammonium component having the following formula: $-R^1-$

$(CH_2)_n$-$[N^+(R^2)(R^3)(R^4)](X^-)$ wherein n is any integer from 1 to 18; R^1 is C(O)O or C(O)NH; R^2 and R^3 are each independently an optionally substituted alkyl or optionally substituted aryl and R^4 is an optionally substituted C_{14} to C_{24} alkyl, or R^2 and R^3 are taken together to form a ring and R^4 is H or absent; and X is selected from the group consisting of Cl, Br, I and OSO_3CH_3; and a second pendant group comprising an organosilane component, wherein the first pendant group is derived from a first monomer comprising the quaternary ammonium component, and the second pendant group is derived from a second monomer comprising the organosilane component, wherein the ratio of the first monomer comprising the quaternary ammonium component to the second monomer comprising the organosilane component is in the range of about 100:1 to 4:1 by weight,.

Advantageously, the polymer of the present disclosure is a more durable, stable and contact-active antimicrobial coating. In an embodiment, the polymer of the present disclosure comprises an antimicrobial quaternary ammonium compound moiety and an anchoring alkoxysilane functional group. Consisting of a permanent positive charge on the quaternary nitrogen, the polymer may attach itself via electrostatic attraction onto negatively charged microbial surfaces, such as bacteria. This attachment may impair the microbe's physiological functions by causing the microbe to lose electrical balance, destroying the cell membrane and ultimately leading to cell death. Additionally, the quaternary ammonium compound may insert its hydrophobic alkyl tail in to the cell cytoplasmic membrane where the hydrophobic interaction increases surface pressure and further disrupts cell membrane fluidity to cause cell death.

Further advantageously, the alkoxysilane functional group may be hydrolysed into reactive silanol that may cross-link with other silanol groups on substrate surfaces via condensation reactions. This may allow alkoxysilane-containing molecules to adhere covalently onto the surface via a siloxane bond. Siloxane bond cross-linking using the polymer of the present disclosure may be applied in a variety of materials including rubber, cotton or steel on top of silica-rich materials. Further advantageously, the polymer of the present disclosure is less sensitive to pH or inactivating enzymes as it is a synthetic molecule with a permanent charge.

n is any integer from 1 to 18; R^1 is C(O)O or C(O)NH; R^2, R^3 and R^4 are each independently an optionally substituted alkyl, optionally substituted aryl, or R^2 and R^3 are taken together to form a ring and R^4 is H or absent; and X is selected from the group consisting of Cl, Br, I and OSO_3CH_3; and a second monomer comprising an organosilane component, provided that no other monomer is contacted with the first and second monomer in the polymer.

In another aspect, there is provided a method for preparing an antimicrobial coating compositionas defined above, comprising preparing a polymer, which comprises the steps of contacting a first monomer with a second monomer in conditions suitable for polymerization, wherein a first monomer comprising a quaternary ammonium component having the following formula: $-R^1-(CH_2)_n-[N^+(R^2)(R^3)(R^4)](X^-)$ wherein n is any integer from 1 to 18; R^1 is C(O)O or C(O)NH; R^2 and R^3 are each independently an optionally substituted alkyl or optionally substituted aryl and R^4 is an optionally substituted C_{14} to C_{24} alkyl, or R^2 and R^3 are taken together to form a ring and R^4 is H or absent; and X is selected from the group consisting of Cl, Br, I and OSO_3CH_3; and a second monomer comprising an organosilane component, provided that no other monomer is contacted with the first and second monomer in the polymer, wherein the ratio of the first monomer comprising the quaternary ammonium component to the second monomer comprising the organosilane component is in the range of about 100:1 to 4:1 by weight.

Advantageously, the polymer of the present disclosure may contain, for example, 90 wt% of the first monomer comprising a quaternary ammonium component, and 10 wt% of the second monomer comprising a organosilane component. Advantageously, this may allow for maximum antimicrobial efficacy by the quaternary ammonium component while maintaining sufficient anchoring of the polymer to a substrate via the organosilane component.

In another example, there is provided a polymer obtainable by the method as defined above.

In another aspect, there is provided an antimicrobial coating composition obtainable by the method as defined above.

In another example, there is provided an article comprising the polymer as defined above and a substrate comprising a surface.

In another aspect, there is provided an article comprising the antimicrobial coating composition as defined above and a substrate comprising a surface.

Advantageously, the article comprising the polymer as defined above may also have all the same advantages conferred by the polymer as defined above.

In another example, there is provided a method for preparing the article as defined above, comprising the steps of: forming the polymer as defined above; and contacting the polymer with the surface of the substrate under conditions suitable to adhere the polymer to the surface of the substrate.

In another aspect, there is provided a method for preparing the article as defined above, comprising the steps of: providing the antimicrobial coating composition as defined above; and contacting the antimicrobial coating composition with the surface of the substrate under conditions suitable to adhere the antimicrobial coating composition to the surface of the substrate.

Advantageously, the use of a direct coating method using alkoxysilane may eliminate the need for elaborated coating procedures.

In an embodiment, the method may comprise the step of pre-treating the surface of the substrate prior to the contacting step, wherein the pre-treatment step comprises plasma cleaning. Advantageously, plasma cleaning may change the surface property, for example, by increasing the surface energy and roughness of the substrate, to facilitate adhesion of the polymer.

In another example, there is provided the use of the polymers as defined above as surface coatings.

In another aspect, there is provided the use of the antimicrobial coating composition as defined above as a surface coating.

Definitions

The following words and terms used herein shall have the meaning indicated:

The term “antimicrobial” refers to material that kills microorganisms or inhibits their growth.

The term “pendant group” refers to a group that is not part of the main backbone chain of the polymer.

Claims

1. An antimicrobial coating composition comprising a polymer having a plurality of pendant groups, wherein the pendant groups comprise:

a first pendant group comprising a quaternary ammonium component having the following formula:

$$-R^1-(CH_2)_n-[N^+(R^2)(R^3)(R^4)](X^-)$$

wherein n is any integer from 1 to 18;

R^1 is C(O)O or C(O)NH;

R^2 and R^3 are each independently an optionally substituted alkyl or optionally substituted aryl and R^4 is an optionally substituted C_{14} to C_{24} alkyl, or $R^2$and R^3 are taken together to form a ring and R^4 is H or absent;

X is selected from the group consisting of Cl, Br, I and OSO_3CH_3; and

a second pendant group comprising an organosilane component,

wherein the first pendant group is derived from a first monomer comprising the quaternary ammonium component, and the second pendant group is derived from a second monomer comprising the organosilane component, wherein the ratio of the first monomer comprising the quaternary ammonium component to the second monomer comprising the organosilane component is in the range of about 100:1 to 4:1 by weight,

provided that the polymer is free of any other pendant groups.

2. The coating composition according to claim 1, wherein R^1 is C(O)O.

3. The coating composition according to claim 1 or 2, wherein n is 2.

4. The coating composition according to any one of the preceding claims, wherein R^2 and R^3 are each independently an optionally substituted C_1 to C_6 alkyl.

5. The coating composition according to claim 4, wherein R^2 and R^3 are both methyl.

6. The coating composition according to any one of the preceding claims, wherein the quaternary ammonium component has the following formula:

$$-C(O)O-(CH_2)_2-[N^+(CH_3)_2(R^4)](X^-).$$

7. The coating composition according to claim 6, R^4 is C_{16} H_{33}.

8. The coating composition according to any one of the preceding claims, wherein the quaternary ammonium component has the following formula:

$$-C(O)O-(CH_2)_2-N^+(CH_3)_2(C_{16}H_{33})(X^-).$$

9. The coating composition according to any one of the preceding claims, wherein the first monomer comprising the quaternary ammonium component is [2-(methacryloyloxy)ethyl]dimethyl hexadecyl ammonium bromide.

10. The coating composition according to claim 1 or 2, wherein n is 12 or 16.

11. The coating composition according to any one of claims 1 to 3, wherein $R^2$and R^3 are taken together to form a heterocyclic ring, and R^4 is H or absent.

12. The coating composition according to claim 11, wherein the heterocyclic ring is pyridine.

13. The coating composition according to any one of the preceding claims, wherein the organosilane component is organosilane or an organic silane ester.

14. The coating composition according to claim 13, wherein the organosilane component has the following formula:

$$-R^5-(CH_2)_m-Si(-O-R^6)_3,$$

wherein m is any integer from 1 to 6;

R^5 is C(O)O or C(O)NH; and

R^6 is selected from the group consisting of H, an optionally substituted alkyl and a silane ester.

15. The coating composition according to claim 14, wherein R^5 is C(O)O.

16. The coating composition according to claim 14 or 15, wherein R^6 is an optionally substituted C_1 to C_5 alkyl.

17. The coating composition according to claim 16, wherein R^6 is methyl.

18. The coating composition according to any one of claims 14 to 17, wherein the organosilane component has any one of the following formulas:

$$-C(O)O-(CH_2)_3-Si(-O-CH_3)_3,$$

$$-C(O)O-(CH_2)_3-Si(-O-H)_3, \text{ or}$$

$$-C(O)O-(CH_2)_3-Si(-O-Si-R^7)_3,$$

wherein R^7 is an optionally substituted alkyl.

19. The coating composition according to claim 18, wherein the organosilane component has the following formula:

$$-C(O)O-(CH_2)_3-Si(-O-Si-CH_3)_3.$$

20. The coating composition according to any one of the preceding claims, wherein the second monomer comprising the organosilane component is 3-trimethylsilylpropyl methacrylate.

21. The coating composition according to any one of the preceding claims, wherein the polymer is diluted to a final concentration of 1 wt. % to about 20 wt. % in a solvent.

22. An antimicrobial coating composition comprising a polymer having a plurality of pendant groups, wherein the pendant groups consists of:

a first pendant group comprising a quaternary ammonium component having the following formula:

$$-R^1-(CH_2)_n-[N^+(R^2)(R^3)(R^4)](X^-)$$

wherein n is any integer from 1 to 18;

R^1 is C(O)O or C(O)NH;

R^2 and R^3 are each independently an optionally substituted alkyl or optionally substituted aryl and R^4 is an optionally substituted C_{14} to C_{24} alkyl, or R^2 and R^3 are taken together to form a ring and R^4 is H or absent;

and X is selected from the group consisting of Cl, Br, I and OSO_3CH_3; and

a second pendant group comprising an organosilane component,

wherein the first pendant group is derived from a first monomer comprising the quaternary ammonium component, and the second pendant group is derived from a second monomer comprising the organosilane component, wherein the ratio of the first monomer comprising the quaternary ammonium component to the second monomer comprising the organosilane component is in the range of about 100:1 to 4:1 by weight.

23. A method for preparing an antimicrobial coating composition according to any one of claims 1 to 22, comprising preparing a polymer, which comprises the steps of contacting a first monomer with a second monomer in conditions suitable for polymerization, wherein

a first monomer comprising a quaternary ammonium component having the following formula:

$$-R^1-(CH_2)_n-[N^+(R^2)(R^3)(R^4)](X^-)$$

wherein n is any integer from 1 to 18;

R^1 is C(O)O or C(O)NH;

R^2 and R^3 are each independently an optionally substituted alkyl or optionally substituted aryl and R^4 is an optionally substituted C_{14} to C_{24} alkyl, or R^2 and R^3 are taken together to form a ring and R^4 is H or absent;

and

X is selected from the group consisting of Cl, Br, I and OSO_3CH_3; and

a second monomer comprising an organosilane component,

provided that no other monomer is contacted with the first and second monomer in the polymer, wherein the ratio of the first monomer comprising the quaternary ammonium component to the second monomer comprising the organosilane component is in the range of about 100:1 to 4:1 by weight.

24. The method according to claim 23, wherein the first monomer comprising the quaternary ammonium component and the second monomer comprising an organosilane component comprise a methacrylate group.

25. The method according to claim 23 or 24, wherein the first monomer comprising the quaternary ammonium component is 2-(methacryloyloxy)ethyl]dimethyl hexadecyl ammonium bromide and the second monomer comprising the organosilane component is 3-trimethylsilylpropyl methacrylate.

26. An antimicrobial coating composition obtainable by the method according to any one of claims 23 to 25.

27. An article comprising the antimicrobial coating composition of any one of claims 1 to 22 and a substrate comprising a surface.

28. The article according to claim 27, wherein the antimicrobial coating composition is adhered to the surface of the substrate.

29. The article according to claim 27 or 28, wherein the substrate comprises a material selected from the group consisting of non-siliceous ceramic material, siliceous material, metal, metal oxide, polymer and any mixture thereof.

30. The article according to any one of claims 27 to 29, wherein the substrate is in a form selected from the group consisting of film, sheet, tube, fiber, needle and any mixture thereof.

31. The article according to any one of claims 27 to 30, wherein the article is a medical device.

32. The article according to any one of claims 27 to 31, wherein article is a microneedle.

33. A method for preparing the article of any one of claims 27 to 32, comprising the steps of:

providing the antimicrobial coating composition of any one of claims 1 to 22; and

contacting the antimicrobial coating composition with the surface of the substrate under conditions suitable to adhere the antimicrobial coating composition to the surface of the substrate.

34. The method of claim 33, wherein the antimicrobial coating composition is solubilized in a solvent.

35. The method of claim 33 or 34, wherein the contacting step further comprises adding a catalyst.

36. The method of claim 35, wherein the catalyst is an acid.

37. The method of any of claims 35 to 36, comprising the step of pre-treating the surface of the substrate prior to the contacting step.

38. The method of claim 37, wherein the pre-treatment step comprises plasma cleaning.

39. The use of the antimicrobial coating composition of any one of claims 1 to 22 as a surface coating.