common. Unfortunately, conventional fabrics have been found to deteriorate and lose antimicrobial properties during repeated uses and/or wash cycles.

[0005] Additionally, many purported antimicrobial fabrics do not demonstrate sufficient antimicrobial properties, nor do they retain these properties for the lifetime of the product in which they are utilized. In some instances, the antimicrobial additives may have adverse environmental consequences due to leaching from the fabric.

[0006] As one example of conventional antimicrobial yarns and fabrics, US Patent No. 6,584,668 discloses durable non-electrically conductive metal treatments applied to yarns and textile fabrics. The durable non-electrically conductive metal treatments are coatings or finishes applied to yarns and textile fabrics. The metal treatments may include silver and/or silver ions, zinc, iron, copper, nickel, cobalt, aluminum, gold, manganese, magnesium, and the like. The metal treatments are applied to the exterior surface of the yarn or fabric as a coating or film.

[0007] In addition, US Patent 4,701,518 discloses an antimicrobial nylon prepared in water with a zinc compound (ZnO) and phosphorus compound to form carpet fibers. The process produces nylon fibers for carpets having 18 denier per filament (dpf), and are prepared by conventional melt polymerization. Such carpet fibers typically have average diameters that are well above 10 microns, which are generally unsuitable for next-to-skin applications.

[0008] Although some references may teach the use of antimicrobial fibers and fabrics, a need still exists for antimicrobial fibers and fabrics that retain their antimicrobial properties after multiple washes, while maintaining fiber strength.

SUMMARY

[0009] According to one example, the present disclosure relates to a polymer resin composition having permanent antimicrobial properties comprising: a polymer; less than 2500 ppm of zinc dispersed within the polymer; and less than 1000 ppm of phosphorus; wherein the weight ratio of the zinc to the phosphorus is: at least 1.3:1; or less than 0.64:1. In one aspect, the present disclosure refers to a polymer resin composition having permanent antimicrobial properties comprising: a polymer; less than 2500 ppm of zinc dispersed within the polymer; less than 1000 ppm of phosphorus; wherein the weight ratio of the zinc to the phosphorus is: at least 1.3:1; or less than 0.64:1; and wherein the relative viscosity of the polymer resin composition ranges from 5 to 100~~is less than 100~~. In some examples, the weight ratio of the zinc to the phosphorus is at least 2:1. In some examples, the relative viscosity of the polymer resin composition ranges from 20 to 100. In some examples,

the polymer resin composition comprises from 200 ppm to 600 ppm zinc, optionally less than 700 ppm of zinc, e.g., less than 500 ppm zinc. In some examples, the polymer resin composition comprises a delusterant including at least a portion of the phosphorus. In some examples, there is no phosphorus in the polymer resin composition. The zinc may be provided via a zinc compound comprising zinc oxide, zinc acetate, zinc ammonium carbonate, zinc ammonium adipate, zinc stearate, zinc phenyl phosphinic acid, zinc pyrithione and/or combinations thereof. In some examples, the zinc compound is not zinc phenyl phosphinate and/or zinc phenyl phosphonate and/or zinc ammonium adipate. In some examples, the phosphorus may be provided via a phosphorus compound comprising phosphoric acid, benzene phosphinic acid, benzene phosphonic acid, manganese hypophosphite, sodium hypophosphite, monosodium phosphate, hypophosphorous acid, phosphorous acid, and/or combinations thereof. In one example, the polymer resin composition comprises less than 700 ppm zinc, e.g., less than 500 ppm of zinc, the polymer resin composition comprises a delusterant including at least a portion of the phosphorus, and fibers formed from the polymer resin composition inhibit greater than 89% of *S. Aureus* as measured by ISO 20743:2013 and optionally have a zinc retention greater than 20%, e.g., greater than 45%. In one example, the polymer comprises a nylon, the zinc is provided in the form of zinc oxide and/or zinc pyrithione, and the relative viscosity of the polymer resin composition ranges from 20 to 100. In one example, the polymer comprises nylon-6,6, the zinc is provided in the form of zinc oxide, the weight ratio of zinc to phosphorus is at least 2:1, and fibers formed from the polymer resin composition inhibits greater than 95% of *S. Aureus* as measured by ISO 20743:2013 and optionally have a zinc retention greater than 60%. The polymer resin composition may further comprise one or more additional antimicrobial agents comprising silver, tin, copper, and gold, and alloys, oxides, and/or combinations thereof.

[0010] In some examples, the present disclosure relates to an antimicrobial fiber having permanent antimicrobial properties comprising: a polymer; less than 2500 ppm of zinc dispersed within the polymer; and less than 1000 ppm of phosphorus; and wherein the denier of the antimicrobial fiber is less than 12 dpf. In one aspect, the present disclosure refers to antimicrobial fibers having permanent antimicrobial properties comprising: a polymer composition comprising: a polymer; less than 2500 ppm of zinc dispersed within the polymer; and less than 1000 ppm of phosphorus; wherein the weight ratio of the zinc to the phosphorus is: at least 1.3:1; or less than 0.64:1; wherein the relative viscosity of the polymer composition ranges from 5 to 100~~is less than 100~~; and wherein the denier of the antimicrobial fiber is less than 12 dpf. In some examples, the weight ratio of the zinc to the phosphorus is: at least 1.3:1; or less than 0.64:1. In some examples, the weight ratio of the zinc to the phosphorus is at least 2:1. In some examples, the fibers have an average diameter less

aqueous monomer solution to form a polymer melt; and extruding the polymer melt to form an antimicrobial fiber, wherein the weight ratio of zinc to phosphorus is: at least 1.3:1; or less than 0.64:1, wherein the denier of the antimicrobial fiber is less than 12 dpf. In one aspect, the present disclosure refers to a process for preparing antimicrobial fibers having permanent antimicrobial properties, the process comprising: preparing an aqueous monomer solution; adding less than 2500 ppm of zinc dispersed within the aqueous monomer solution; adding less than 1000 ppm of phosphorus; polymerizing the aqueous monomer solution to form a polymer melt; and extruding the polymer melt to form the antimicrobial fibers, wherein the relative viscosity of the polymer composition ranges from 5 to 100~~is less than 100~~; wherein the weight ratio of zinc to phosphorus is: at least 1.3:1 or less than 0.64:1; and wherein the antimicrobial fibers have a denier per filament of less than 12 dpf. The process may further comprise spinning the antimicrobial fiber to form a yarn; and dyeing the yarn. In some examples, the polymer comprises from 200 ppm to 600 ppm zinc, optionally less than 700 ppm of zinc, e.g., less than 500 ppm zinc. In some examples, the antimicrobial fiber has a zinc retention greater than 45%, e.g., greater than 70%,. In some examples, the step of adding phosphorus comprises adding a delusterant including at least a portion of the phosphorus. In some cases the process further comprises the step dyeing the antimicrobial fibers using a dye recipe to form dyed antimicrobial fibers; wherein the dye recipe has a pH ranging from 3.0 to 7.0; and wherein the dyed antimicrobial fibers have a zinc retention greater than 20%, and/or the steps of forming a yarn or fabric from the antimicrobial fibers; and dyeing the yarn or fabric.

[0012] In some examples, the present disclosure relates to qntimicrobial fibers having permanent antimicrobial properties comprising: a polymer; zinc dispersed within the polymer; and less than 1000 ppm of phosphorus; wherein the antimicrobial fibers demonstrate a zinc retention greater than 20%, after a dye bath using a dye recipe having a pH values, e.g., less than 5.0. In one aspect, the present disclosure refers to antimicrobial fibers having permanent antimicrobial properties comprising: a polymer composition comprising: a polymer; zinc dispersed within the polymer; and less than 1000 ppm of phosphorus; wherein the weight ratio of the zinc to the phosphorus is: at least 1.3:1; or less than 0.64:1; wherein the relative viscosity of the polymer composition ranges from 5 to 100~~is less than 100~~; and wherein the antimicrobial fibers demonstrate a zinc retention greater than 20%, after a dye bath using a dye recipe having a pH values, e.g., less than 5.0.

DETAILED DESCRIPTION

Introduction

[0013] As discussed above, some conventional antimicrobial fibers and fabrics utilize antimicrobial compounds to inhibit bacterial growth and/or protect the fibers and fabrics. For example, some fabrics may include antimicrobial additives, e.g., silver, coated or applied as a film on an exterior layer. However, it has been found that these treatments or coatings often leach from the fabric. Likewise, in non-coating applications where the antimicrobial additives are a component of the fiber, the antimicrobial additives have also been known to wash out, usually within about 10 wash-cycles, leaching the additives into the environment.

[0014] Also, the references that relate to higher denier (for example, greater than 12 dpf) and/or higher fiber diameter (for example, greater than 20 microns) fibers/filaments, e.g.,

We Claim:

1. A polymer resin composition having permanent antimicrobial properties comprising:

    a polymer;

    less than 2500 ppm of zinc dispersed within the polymer;

    less than 1000 ppm of phosphorus;

    wherein the weight ratio of the zinc to the phosphorus is:

        at least 1.3:1; or

        less than 0.64:1; and

    wherein the relative viscosity of the polymer resin composition ranges from 5 to 100~~is less than 100~~.

2. The polymer resin composition of claim 1, wherein the weight ratio of the zinc to the phosphorus is at least 2:1.

3. The polymer resin composition of claim 1, wherein the relative viscosity of the polymer resin composition ranges from 20 to 100.

4. The polymer resin composition of claim 1, wherein the polymer resin composition comprises from 200 ppm to 600 ppm of zinc.

5. The polymer resin composition of claim 1, wherein the polymer resin composition comprises a delusterant including at least a portion of the phosphorus.

6. The polymer resin composition of claim 1, wherein dyed antimicrobial fibers formed from the polymer resin composition have a zinc retention greater than 40%, when the fibers are dyed using a dye recipe having a pH greater than 4.5.

7. The polymer resin composition of claim 1, wherein dyed antimicrobial fibers formed from the polymer resin composition have a zinc retention greater than 20%, when the fibers are dyed using a dye recipe having a pH less than 5.0.

8. The polymer resin composition of claim 1, wherein the zinc is provided via a zinc compound comprising zinc oxide, zinc acetate, zinc ammonium carbonate, zinc ammonium adipate, zinc stearate, zinc phenyl phosphinic acid, zinc pyrithione and/or combinations thereof.

9. The polymer resin composition of claim 1, wherein the phosphorus is provided via a phosphorus compound comprising phosphoric acid, benzene phosphinic acid, benzene phosphonic acid, manganese hypophosphite, sodium hypophosphite, monosodium phosphate, hypophosphorous acid, phosphorous acid, and/or combinations thereof.

10. The polymer resin composition of claim 1, wherein the polymer resin composition comprises less than 700 ppm of zinc, wherein the polymer resin composition comprises a delusterant including at least a portion of the phosphorus, wherein fibers formed from the polymer resin composition inhibits greater than 89% of *S. Aureus* as measured by ISO 20743:2013, and wherein dyed antimicrobial fibers formed from the polymer resin composition have a zinc retention greater than 45%, when the fibers are dyed using a dye recipe having a pH greater than 4.5.

11. The polymer resin composition of claim 1, wherein the polymer comprises nylon-6,6, wherein the zinc is provided via zinc oxide, wherein the weight ratio of zinc to phosphorus is at least 2:1, wherein the polymer resin composition inhibits greater than 95% of *S. Aureus* as measured by ISO 20743:2013, and wherein dyed antimicrobial fibers formed from the polymer resin composition have a zinc retention greater than 60%, when the fibers are dyed using a dye recipe having a pH greater than 4.5.

12. Antimicrobial fibers having permanent antimicrobial properties comprising:

    a polymer composition comprising:

    a polymer;

    less than 2500 ppm of zinc dispersed within the polymer; and

less than 1000 ppm of phosphorus;

wherein the weight ratio of the zinc to the phosphorus is:

at least 1.3:1; or

less than 0.64:1;

wherein the relative viscosity of the polymer composition ranges from 5 to 100~~is less than 100~~; and

wherein the denier of the antimicrobial fiber is less than 12 dpf.

13. The antimicrobial fibers of claim 12~~2~~, wherein the weight ratio of zinc to phosphorus is:

at least 1.3:1; or

less than 0.64:1.

14. The antimicrobial fibers of claim 12~~2~~, wherein the fibers have an average diameter less than 20 microns.

15. The antimicrobial fibers of claim 12~~2~~, wherein the fibers comprise 200 ppm to 600 ppm of zinc.

16. The antimicrobial fibers of claim 12~~2~~, wherein the antimicrobial fibers have a zinc retention greater than 20%.

17. The antimicrobial fibers of claim 12~~2~~, wherein the polymer comprises less than 700 ppm of zinc, wherein the polymer comprises a delusterant including at least a portion of the phosphorus, wherein the antimicrobial fibers inhibit greater than 89% of *S. Aureus* as measured by ISO 20743:2013, and wherein the antimicrobial fibers, when dyed, have a zinc retention greater than 45%, wherein the fibers are dyed using a dye recipe having a pH greater than 4.5.

18. The antimicrobial fibers of claim 12~~2~~, wherein the polymer comprises nylon-6,6, wherein the zinc is provided in the form of zinc oxide and/or zinc pyrithione, and/or zinc

ammonium adipate, wherein the weight ratio of zinc to phosphorus is at least 2:1, wherein the antimicrobial fibers inhibit greater than 95 % of *S. Aureus* as measured by ISO 20743:2013, wherein the antimicrobial fibers, when dyed, have a zinc retention greater than 60%, wherein the fibers are dyed using a dye recipe having a pH greater than 4.5, wherein the antimicrobial fibers have an average diameter less than 10 microns.

19. A process for preparing antimicrobial fibers having permanent antimicrobial properties, the process comprising:

preparing an aqueous monomer solution;

adding less than 2500 ppm of zinc dispersed within the aqueous monomer solution;

adding less than 1000 ppm of phosphorus;

polymerizing the aqueous monomer solution to form a polymer melt; and

extruding the polymer melt to form the antimicrobial fibers,

wherein the relative viscosity of the polymer composition ranges from 5 to 100~~is less than 100~~;

wherein the weight ratio of zinc to phosphorus is: at least 1.3:1 or less than 0.64:1; and

wherein the antimicrobial fibers have a denier per filament of less than 12 dpf.

20. The process of claim 19~~9~~, wherein the polymer comprises 200 ppm to 600 ppm zinc.

21. The process of claim 19~~9~~, wherein the antimicrobial fibers, when dyed, have a zinc retention greater than 45%, when the fibers are dyed using a dye recipe having a pH greater than 4.5.

22. The process of claim 19~~9~~, wherein the step of adding phosphorus comprises adding a delusterant including at least a portion of the phosphorus.

23. The process of claim 19, further comprising the step of:

dyeing the antimicrobial fibers using a dye recipe to form dyed antimicrobial fibers;

wherein the dye recipe has a pH ranging from 3.0 to 7.0; and

wherein the dyed antimicrobial fibers have a zinc retention greater than 20%.

24. The process of claim 23, further comprising the steps of:

forming a yarn or fabric from the antimicrobial fibers; and

dyeing the yarn or fabric.

25. Antimicrobial fibers having permanent antimicrobial properties comprising:

a polymer composition comprising:

a polymer;

zinc dispersed within the polymer; and

less than 1000 ppm of phosphorus;

wherein the weight ratio of the zinc to the phosphorus is:

at least 1.3:1; or

less than 0.64:1;

wherein the relative viscosity of the polymer composition ranges from 5 to 100~~is less than 100~~; and

wherein the antimicrobial fibers demonstrate a zinc retention greater than 20%, after a dye bath using a dye recipe having a pH values, e.g., less than 5.0.