WHAT IS CLAIMED IS:

1. A composition comprising a polyhydroxyalkanoate (PHA) polymer and a viscosity-modifying agent.

2. The composition of claim 1, wherein the viscosity modifying agent comprises an ester,

and optionally the viscosity modifying agent comprises, or further comprises, glycerin, trimethyl propanol (TMP), pentaerythritol, and/or sorbitol.

3. The composition of claim 2, wherein the ester comprises a fatty acid ester of a polyhydroxy alcohol,

and optionally the fatty acid ester comprises lauric acid, myristic acid, palmitic acid, stearic acid, arachidic acid, or behenic acid.

4. The composition of any of claims 1 to 3, wherein the fatty acid ester has a melting point above about 50°C, or between about 50°C and 80°C.

5. The composition of any of claims 1 to 4, wherein the PHA polymer comprises a PHA copolymer.

6. The composition of claim 5, wherein the PHA polymer or the PHA copolymer comprises one or more of 3-hydroxybutyrate (3HB) homopolymer, or a copolymer of 3-hydroxybutyrate (3HB) and 4-hydroxybutyrate (4HB), or a copolymer of 3-hydroxybutyrate (3HB) and 3-hydroxyvalerate (3HV), or a copolymer of 3-hydroxybutyrate (3HB) and 3-hydroxyhexanoate (3HH) polymers.

7. The composition of any of claims 1 to 6, wherein the PHA polymer or the PHA copolymer comprises 8% to 30% 4HB and 92% to 70% 3HB, and an ester with a melting point above 30°C, or above 40°C, or over 50°C, or an ester with a melting point between about 25°C and 75°C.

8. The composition of any of claims 1 to 7, wherein the PHA polymer comprises one or more of 3-hydroxybutyrate or 4-hydroxybutyrate.

9. The composition of any of claims 1 to 8, having a non-tack coating time of less than about 30 seconds, or less than about 10 seconds, or less than about 1 second (sec).

10. The composition of any of claims 1 to 9, wherein the viscosity modifying agent is present in an amount of up to about 15 wt%, or between about 0.5% and 20 wt%, or between about 1% and 15 wt%.

11. The composition of claim 10, wherein the viscosity modifying agent is present in an amount of about 5 wt% to about 15 wt%, about 7 wt% to about 13 wt%, or about 8 wt% to about 12 wt%.

12. The composition of any of claims 1 to 11, further comprising a nucleating agent,

wherein optionally the nucleating agent or agents comprise between about 0.01% to 5%, or 0.1% to 4%, or 0.5% to 3%, of the volume of the PHA composition, or between about 0.05% to 10%, or 0.1% to 3%, or 0.1% to 2% by volume, or about 0.05%, 1%, 2%, 3%, 4% or 5% by volume of the PHA composition.

13. The composition of claim 12, wherein the nucleating agent comprises one, two or several of: sulfur; an erythritol; pentaerythritol; dipentaerythritol; a stearate; sorbitol; mannitol; a polyester wax; a sebacate; a citrate; a fatty ester of adipic, succinic, and/or glucaric acid; a lactate; an alkyl diester; a citrate or citrates; an alkyl methyl esters; a dibenzoate; a clay or clays or a nano clay; calcium carbonate or talc; kaolinite; mont-morillonite; bentonite; silica; chitin; titanium dioxide; mica; propylene carbonate; a caprolactone diol; a poly(ethylene) glycol (PEG); an ester of a vegetable oils; a long chain alkyl acids; an adipate; glycerol; an isosorbide or isosorbide derivative; and, mixtures thereof,

and optionally the nucleating agent or agents comprise propylene carbonate or caprolactone diol, optionally having a number average molecular weight (MW) from between about 1,000 to 4,000 g/mol, or a poly(ethylene) glycols having a number average MW of between about 1,000 to 4,000 g/mol, of an ester or esters of vegetable oils, long chain alkyl acids, adipates, glycerol, isosorbide derivatives or mixtures thereof.

14. The composition of claim 12 or claim 13, wherein the nucleating agent comprises poly-3-hydroxy butyrate (P3-HB),

and optionally the P3-HB comprises or is formulated as a P3-HB powder or powder melt,

and optionally the nucleating agent comprises precipitated calcium carbonate, precipitated or fumed silica, talc, bentonite or montmorillonite clay, calcium sulfate and/or boron nitride,

and optionally the size of the P3-HB powder is less than about 1000 microns, or less than about 100 microns, or less than about 40 microns, or between about 20 microns and 1000 microns.

15. The composition of any of claims 1 to 14, further comprising:

(a) at least one antioxidant, wherein optionally the antioxidant comprises sorbic acid, butylated hydroxytoluene (BHT), butylated hydroxyanisole (BHA) or a combination thereof;

(b) an antimicrobial, wherein optionally the antimicrobial comprises BHT, BHA, benzoic acid, ascorbic acid or a combination thereof;

(c) a dispersant, wherein optionally the dispersant comprises an ester of an unsaturated acid or a polyacrylic acid or a combination thereof;

(d) a thickener or a viscosity modifier, wherein optionally the thickener or the viscosity modifier comprises glycerin mono stearate (GMS), an alginate, a polyvinyl alcohol or a combination thereof;

(e) an ultraviolet light inhibitor, wherein optionally the ultraviolet light inhibitor comprises a hindered amine light stabilizers, a stearate of magnesium or zinc, or a combination thereof;

(f) a stabilizer, wherein optionally a heat stabilizer, wherein optionally the stabilizer comprises polyvinyl alcohol (PVOH), vinyl alcohol, a soaps of a fatty acid, pyrrolidone, an ethylene oxide, a propylene oxide or a combination thereof;

(g) an emulsifying agent, wherein optionally the emulsifying agent comprises a polyethylene oxide addict a of fatty acid and fatty alcohol, or a polysorbate;

(h) an anti-blocking agent, wherein optionally the anti-blocking agent comprises: an inorganic mineral pigment; a diatomaceous earth; talc; sodium or potassium aluminosilicate; a mineral mixture of sodium and potassium aluminosilicates; or, a silica, optionally a synthetic, amorphous silica; or

(i) any combination of (a) to (h).

16. A composite structure or product of manufacture comprising composition as set forth in any of claims 1 to 15, or any of the preceding claims.

17. A composite structure or product of manufacture comprising a substrate and a coating comprising the composition as set forth in any of claims 1 to 15, or any of the preceding claims.

18. The composite structure or product of manufacture of claim 16 or claim 17, wherein the substrate comprises a paper or a paperboard stock, or a cellulose fiber-comprising packaging material.

19. The composite structure or product of manufacture of any of claims 16 to 18, wherein the coating has a thickness of about 5 millimeters (mm), or between about 0.25 to 20 mm, or between about 0.5 to 20 mm, or between about 1 to 10 mm.

20. A method of producing a polyhydroxyalkanoate (PHA) polymer powder comprising: steps as set forth in FIG. 1, or the following steps:

(a) adding a substrate, a PHA-producing microorganism (optionally a methanotrophic microorganism), micronutrients and oxygen to a culture vessel or a fermentation reaction vessel or equivalent;

(b) culturing the microorganism in the culture vessel or the fermentation reaction vessel or equivalent;

(c) separating the PHA from the cultured microorganism, optionally the separate comprises filtration or centrifugation;

(d) suspending the PHA in water, optionally using purified or distilled water;

(e) centrifuging and/or filtering the PHA suspension to remove any remaining non-PHA debris from the microorganism to generate a purified PHA; and

(f) spray-drying the purified PHA to generate a PHA powder.

21. A method of producing a polyhydroxyalkanoate (PHA) composition or dispersion comprising: steps as set forth in FIG. 2 and FIG. 3, or the following steps:

(a) inputting or injecting a PHA pellet or powder into a polymer jet micronizer, thereby producing micronized PHA powder;

(b) adding the micronized PHA powder, optionally with at least one additive, and water into a reaction vessels to generate a PHA aqueous solution or a PHA suspension, wherein optionally water comprises about 50% to 60% of the volume of the aqueous solution or a PHA suspension,

and optionally the at least one additive comprises a nucleating agent or a plasticizer; and

(c) adding the PHA aqueous or water-based solution or the PHA suspension to a high shear mixer to generate a PHA dispersion,

and optionally a step (d) packaging the PHA aqueous or water-based dispersion, optionally into totes.

22. The method of claim 21, wherein the additive comprises:

(a) at least one antioxidant, wherein optionally the antioxidant comprises sorbic acid, butylated hydroxytoluene (BHT), butylated hydroxyanisole (BHA) or a combination thereof;

(b) an antimicrobial, wherein optionally the antimicrobial comprises BHT, BHA, benzoic acid, ascorbic acid or a combination thereof;

(c) a dispersant, wherein optionally the dispersant comprises an ester of an unsaturated acid or a polyacrylic acid or a combination thereof;

(d) a thickener or a viscosity modifier, wherein optionally the thickener or the viscosity modifier comprises glycerin mono stearate (GMS), an alginate, a polyvinyl alcohol or a combination thereof;

(e) an ultraviolet light inhibitor, wherein optionally the ultraviolet light inhibitor comprises a hindered amine light stabilizers, a stearate of magnesium or zinc, or a combination thereof;

(f) a stabilizer, wherein optionally a heat stabilizer, wherein optionally the stabilizer comprises polyvinyl alcohol (PVOH), vinyl alcohol, a soaps of a fatty acid, pyrrolidone, an ethylene oxide, a propylene oxide or a combination thereof;

(g) an emulsifying agent, wherein optionally the emulsifying agent comprises a polyethylene oxide addict a of fatty acid and fatty alcohol, or a polysorbate;

(h) an anti-blocking agent, wherein optionally the anti-blocking agent comprises: an inorganic mineral pigment; a diatomaceous earth; talc; sodium or potassium aluminosilicate; a mineral mixture of sodium and potassium aluminosilicates; or, a silica, optionally a synthetic, amorphous silica;

(i) a viscosity modifying agent, wherein optionally the viscosity modifying agent comprises an ester, or optionally the viscosity modifying agent comprises glycerin, trimethyl propanol (TMP), pentaerythritol, and/or sorbitol; or

(j) any combination of (a) to (i).

23. A method of producing a polyhydroxyalkanoate (PHA) polymer melt comprising: steps as set forth in FIG. 4, or the following steps:

(a) melting a PHA powder to generate a melt extrusion; and

(b) pelletilizing the PHA melt extrusion, optionally pelletilizing by using an extruder,

and optionally a step (c) packaging the PHA extrusion, wherein optionally the PHA extrusion is fabricated as a pellet or a powder, and optionally packaging into totes or a container.

24. A polyhydroxyalkanoate (PHA) composition comprising:

(a) a copolymer of PHA comprising

(i) between about 8% to 24% 4-HB and

(ii) between about 92% to 76% 3-HB and

(b) an ester having a melting point above about 30°C, or above 50°C, or having a melting point between about 30°C and 75°C, or having a melting point between about 40°C and 60°C.

25. The PHA composition of claim 23, wherein the PHA copolymer comprises about 16% 4-HB and about 84% 3-HB.

26. The PHA composition of claim 23 or claim 24, wherein the ester is a reacted product of a saturated fatty acid and a polyhydroxy alcohol.

27. The PHA composition of any of claims 23 to 25, formulated or configured for application to a paper or a paperboard stock as a barrier coating.

28. The PHA composition of any of claims 23 to 26, further comprising a nucleating agent,

wherein optionally the nucleating agent or agents comprise between about 0.01% to 5%, or 0.1% to 4%, or 0.5% to 3%, of the volume of the PHA composition, or between about 0.05% to 10%, or 0.1% to 3%, or 0.1% to 2% by volume, or about 0.05%, 1%, 2%, 3%, 4% or 5% by volume of the PHA composition.

29. The PHA composition of claim 27, wherein the nucleating agent comprises a P3-HB, and optionally the P3-HB comprises a P3-HB powder,

wherein optionally the P3-HB or P3-HB powder comprises between about 0.05% to 5%, or 0.05% to 10%, or 0.1% to 3%, or 0.1% to 2% by volume, or about 0.05%, 1%, 2%, 3%, 4% or 5% by volume of the PHA composition.

30. The PHA composition of any of claims 23 to 28, further comprising a high melting point ester,

wherein optionally the high melting ester comprises a fatty acid ester,

and optionally the high melting point ester comprises a micronized high melting point ester, and optionally the high melting point is between about 25°C and 75°C, or is above about 30°C, or above about 40°C, or above about 50°C, or above about 60°C, or optionally the ester has a melting point between about 50°C and 80°C.

31. The PHA composition of any of claims 23 to 29, formulated as or made into a dispersion in water, optionally formulated as or made into a dispersion from the fermentation broth or after micronization of a PHA homopolymer, optionally a purified PHA homopolymer, and optionally the PHA homopolymer comprises: P-

3HB or a PHA copolymers, or one or more of 3-hydroxybutyrate (3HB) homopolymer, or a copolymer of 3-hydroxybutyrate (3HB) and 4-hydroxybutyrate (4HB), or a copolymer of 3-hydroxybutyrate (3HB) and 3-hydroxyvalerate (3HV), or a copolymer of 3-hydroxybutyrate (3HB) and a 3-hydroxyhexanoate (3H) polymer, and the high-melting point ester.

32. A method of forming a water-based dispersion of a copolymer of PHA comprising: generating or obtaining the copolymer of PHA as a slurry or broth after cell fermentation to biosynthesize the PHA, followed by removing of cell debris and/or contaminants, optionally removing of cell debris by a process comprising cell disruption and/or enzymatic or light alkaline water washing.

33. A product of manufacture comprising: paper or cardboard; a cellulose fiber-comprising packaging material, a plastic, a paint, a coating, an ink, an adhesive, a device and/or a fiber comprising: a composition of any of claims 1 to 15, or a composite structure or product of manufacture of any of claims 16 to 19, or a PHA composition of any of claims 23 to 30.

34. The product of manufacture of claim 32, wherein the plastic is or comprises:

a single-use plastic or a long-lasting plastic or plastic application,

an acrylic, a polyester, a silicone, a polyurethane or a halogenated plastic,

a conductive plastic, and optionally the conductive plastic comprises a polyacetylene,

a thermoplastic, and optionally the thermoplastic comprises polyethylene (PE), polypropylene (PP), polystyrene (PS) and/or polyvinyl chloride (PVC),

an amorphous plastic, and optionally the amorphous plastic comprises a methyl methacrylate (PMMA),

a crystalline plastic, and optionally the crystalline plastic comprises high-density polyethylene (HDPE), polybutylene terephthalate (PBT) and/or polyether ether ketone (PEEK), or

any combination thereof.

35. The product of manufacture of claim 32 or claim 33, wherein the fiber is used or fabricated as a woven fiber or nonwoven fiber, and optionally the product of manufacture comprises a diaper, a tissue, a fabric or a coating, and optionally the coating is placed or fabricated on a solid, flexible or semi-solid substrate, and optionally the solid, flexible or semi-solid substrate comprises a paper or a paperboard product.

36. The product of manufacture of any of claims 32 to 34, wherein the device is a medical device, optionally a medical device for *in vivo* use, and optionally the medical device is an implant, a pin, a rod, a substrate for cells, an artificial organ, a suture or a mesh, and optionally the composition or the composite structure acts or is a coating on the medical device.

CLAIMS

1. A method of forming a polyhydroxyalkanoate (PHA) copolymer, comprising:

generating a copolymer of PHA as a slurry or broth after cell fermentation to biosynthesize the PHA; and

removing any cell debris and/or contaminants.

2. The method of claim 1, including removing the cell debris by cell disruption and/or enzymatic or light alkaline water washing.

3. The method of claim 1, further comprising suspending the PHA in water to make a dispersion.

4. The method of claim 1, wherein the PHA copolymer comprises 3-hydroxybutyrate (3HB) homopolymer, a copolymer of 3-hydroxybutyrate (3HB) and 4-hydroxybutyrate (4HB), a copolymer of 3-hydroxybutyrate (3HB) and 3-hydroxyvalerate (3HV), or a copolymer of 3-hydroxybutyrate (3HB) and 3-hydroxyhexanoate (3HH) polymers.

5. A method of producing a polyhydroxyalkanoate (PHA) polymer, comprising:

culturing a PHA-producing microorganism, micronutrients, and oxygen in a vessel;

separating PHA from the cultured microorganism;

suspending the PHA in water;

generating a purified PHA from the PHA suspension by removing any remaining non-PHA debris from the microorganism.

6. The method of claim 5, wherein the vessel comprises a culture or fermentation reaction vessel.

7. The method of claim 5, wherein the separation uses filtration or centrifugation.

8. The method of claim 5, wherein the suspension uses purified or distilled water.

9. The method of claim 5, wherein generating the purified PHA comprises centrifuging or filtering.

10. *Intentionally left blank*

11. A composition comprising a polyhydroxyalkanoate (PHA) polymer and up to 15wt% of a viscosity modifying agent comprising a combination of:

an ester of lauric acid, myristic acid, palmitic acid, ~~stearic acid,~~ arachidic acid, or behenic acid; and

glycerin, trimethyl propanol (TMP), pentaerythritol, ~~sorbitol,~~ or combinations thereof.

12. The composition of claim 11, wherein the PHA polymer comprises a PHA copolymer and the PHA polymer or the PHA copolymer comprises 3-hydroxybutyrate (3HB) homopolymer, a copolymer of 3-hydroxybutyrate (3HB) and 4-hydroxybutyrate (4HB), a copolymer of 3-hydroxybutyrate (3HB) and 3-hydroxyvalerate (3HV), or a copolymer of 3-hydroxybutyrate (3HB) and 3-hydroxyhexanoate (3HH) polymers.

13. The composition of claim 12, wherein the PHA polymer or the PHA copolymer comprises 8% to 30% 4HB and 92% to 70% 3HB.

14. The composition of claim 13, wherein the PHA polymer comprises 3-hydroxybutyrate, 4-hydroxybutyrate, or a combination thereof.

15. The composition of claim 11, further comprising about 0.01% to about 5 vol% of a nucleating agent.

16. The composition of claim 11, having a non-tack coating time of less than about 30 seconds.

17. The composition of claim 11, further comprising:

an antioxidant comprising sorbic acid, butylated hydroxytoluene (BHT), butylated hydroxyanisole (BHA), or combination thereof;

an antimicrobial comprising BHT, BHA, benzoic acid, ascorbic acid or combination thereof;

a dispersant comprising an ester of an unsaturated acid, an ester of polyacrylic acid, or combination thereof;

an ultraviolet light inhibitor comprising a hindered amine light stabilizers, a stearate of magnesium or zinc, or combination thereof;

a stabilizer comprising polyvinyl alcohol (PVOH), vinyl alcohol, a soap of a fatty acid, pyrrolidone, an ethylene oxide, a propylene oxide, or combination thereof;

an emulsifying agent comprising a polyethylene oxide addict of a fatty acid and fatty alcohol, a polysorbate, or combination thereor; or

an anti-blocking agent comprising an inorganic mineral pigment, diatomaceous earth, talc, sodium or potassium aluminosilicate, a mineral mixture of sodium and potassium aluminosilicates, a silica, or combinations thereof.

18. A product of manufacture comprising paper, cardboard, a cellulose fiber-comprising packaging material, a plastic, a paint, a coating, an ink, an adhesive, a device, and/or a fiber containing the PHA copolymer made by the method of claim 1.

19. A product of manufacture comprising paper, cardboard, a cellulose fiber-comprising packaging material, a plastic, a paint, a coating, an ink, an adhesive, a device, and/or a fiber containing the the PHA polymer made by the method of claim 5.

20. A product of manufacture comprising paper, cardboard, a cellulose fiber-comprising packaging material, a plastic, a paint, a coating, an ink, an adhesive, a device, and/or a fiber containing the composition of claim 11.