A thermoplastic fiber is formed of a blend including a degradable polymer and a material that generates an agent upon exposure to stimulus that accelerates degradation of the degradable polymer. The degradable polymer can include a biodegradable polymer, such as poly(lactic acid) polymer, and the material that generates an agent upon exposure to stimulus can include a soy-based material.
DEGRADABLE POLYMER FIBERS WITH ENHANCED DEGRADABILITY

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to and the benefit of Provisional Patent Application No. 61/894,746 filed on Oct. 23, 2013, the entire disclosure of which is incorporated herein by reference.

FIELD OF THE INVENTION

[0002] The present invention relates to degradable polymer fibers that can have enhanced degradability.

BACKGROUND OF THE INVENTION

[0003] Synthetic fibers are widely used in a number of applications to provide a variety of products. For example, synthetic fibers can be used in the manufacture of nonwoven fabrics. Nonwoven fabrics, in turn, are widely used in various articles, such as disposable personal care products, medical products, filtration devices, and cigarette filters, among others.

[0004] Conventional synthetic fibers, however, do not naturally degrade. This can create problems associated with the disposal of products containing the same.

[0005] For example, recycling articles containing conventional synthetic fibers is generally not cost effective, yet the disposal of these articles in landfills generates significant amounts of non-degradable waste.

[0006] In addition, users often improperly discard products containing components formed of synthetic fibers, such as cigarettes, by leaving such products on roadways, sidewalks, and the like. A significant amount of litter is in the form of cigarette butts, which can take several years to completely degrade.

[0007] Accordingly, there is increasing demand for degradable synthetic fiber components for various products.

[0008] To address concerns over the issue of solid waste disposal and to reduce issues associated with littering, biodegradable polymers are increasingly used as a replacement for conventional synthetic polymers. Of particular interest is the use of lactic acid to manufacture biodegradable resin.

[0009] Degradable materials can be included in various products to help facilitate the disposal and degradation of the same in landfills. Degradable polymers, however, may not significantly or rapidly degrade unless exposed to particular conditions to initiate the breakdown of the polymeric material. Accordingly, there can still be issues associated with the degradation of products including components formed of degradable polymers, particularly when such products are improperly disposed.

SUMMARY OF THE INVENTION

[0010] The present invention provides a thermoplastic degradable fiber that can have enhanced degradability. The thermoplastic fiber is formed of a blend including a degradable polymer, such as a biodegradable polymer. The blend further includes another material which forms an agent or species that can interact with the degradable polymer to accelerate degradation thereof when the material is subjected to or exposed to an appropriate stimulus. Examples of such stimuli include without limitation water, caustic, heat, radiation, and combinations thereof.

[0011] In exemplary embodiments, the degradable polymer includes poly(lactic acid) (PLA) polymer and the second material includes a soy-based material. The soy-based material may be a refined soy-based material, such as soy flour, which can accelerate hydrolysis of a PLA polymer when exposed to moisture.

[0012] The blend can include the degradable polymer and the material that generates an agent or species upon exposure to stimulus in a weight ratio of about 50:50 to about 99:99:0.01, for example, in a weight ratio of about 90:10 to about 99:1.

[0013] The thermoplastic fiber of the invention can be in various forms, such as but not limited to, continuous filaments, spunbonded filaments, staple fibers, meltblown fibers, nanofibers, nanofilaments, and the like, and combinations thereof.

[0014] The present invention also provides textile structures formed using the thermoplastic fibers. Examples of the textile structures include without limitation nonwoven fabrics, knit fabrics, woven fabrics, and the like, and combinations thereof.

[0015] Still further, the invention provides articles including the thermoplastic fibers of the invention. An exemplary article is a cigarette filter.

DETAILED DESCRIPTION OF THE INVENTION

[0016] The present invention now will be described more fully hereinafter in the following detailed description of the invention, in which some, but not all embodiments of the invention are described. Indeed, this invention may be embodied in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will satisfy applicable legal requirements.

[0017] The terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting of the invention. As used herein the term “and/or” includes any and all combinations of one or more of the associated listed items. As used herein, the singular forms “a,” “an” and “the” are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms “comprises” and/or “comprising,” when used in this specification, may include any or all of the combinations of one or more other features, integers, steps, operations, elements, and/or components, but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

[0018] As used herein, the term “fiber” can refer to fibers of finite length, such as conventional staple fiber, and also to substantially continuous filaments. The term “fiber” also includes spunbonded filaments, meltpblown fibers, fibers produced by electrospinning, nanofibers, nanofilaments, and the like, as known in the art.

[0019] Also as used herein, the term “fibrous materials” can include without limitation the fibers as defined herein (such as staple fibers, continuous filaments, etc.) and also yarns, nonwoven fabrics, woven fabrics, and/or knit fabrics.

[0020] The thermoplastic fiber of the invention is formed of a blend. The blend includes a degradable polymer. The blend further includes a material that upon exposure to appropriate conditions or stimulus can form an agent or species that accelerates degradation of the degradable polymer.

[0021] In exemplary embodiments, the degradable polymer is a biodegradable polymer. Biodegradable polymers are known in the art and generally can be defined as a material
that degrades under aerobic and/or anaerobic conditions in the presence of suitable stimulus, such as bacteria, fungi, algae, and other microorganisms to carbon dioxide/methane, water and biomass, although materials containing heteroatoms can also yield other products such as ammonia or sulfur dioxide. “Biomass” generally refers to the portion of the metabolized materials incorporated into the cellular structure of the organisms present or converted to humus fractions indistinguishable from material of biological origin.

[0022] As a result, the biodegradable fiber, either in its initial form or after incorporation into a fibrous structure, will begin to degrade when exposed to such microorganisms, even if such exposure occurs prior to the expiration of the fiber’s useful life.

[0023] Exemplary biodegradable polymers include, without limitation, polyvinyl alcohol, hydrolyzable aliphatic polyesters such as polybutylene succinate (PBS), hydrolyzable aliphatic polyurethanes, cis-polyisoprene, cis-polybutadiene, poly(caprolactone), hydrolyzable poly(lactic acid) polymers, polyhydroxyalkanoates (PHAs), and the like and copolymers and blends thereof. The skilled artisan will appreciate that when poly(lactic acid) polymer is used, the poly(lactic acid) polymer is first hydrolyzed before microorganisms can consume the hydrolysis products.

[0024] In exemplary embodiments, the degradable polymer is poly(lactic acid) (PLA) polymer. Poly(lactic acid) polymer is a biodegradable polyester polymer generally prepared by the polymerization of lactic acid. However, it will be recognized by one skilled in the art that a chemically equivalent material may also be prepared by the polymerization of lactide. Therefore, as used herein, the term “poly(lactic acid) polymer” is intended to represent the polymer that is prepared by either the polymerization of lactic acid or lactide.

[0025] Lactic acid and lactide are known to be an asymmetrical molecules, having two optical isomers referred to, respectively as the levorotatory (hereinafter referred to as “L”) enantiomer and the dextrorotatory (hereinafter referred to as “D”) enantiomer. As a result, by polymerizing a particular enantiomer or by using a mixture of the two enantiomers, it is possible to prepare polymers that are chemically similar yet which have widely differing properties. In particular, it has been found that by modifying the stereoregularity of a poly(lactic acid) polymer, it is possible to control the melting temperature of the polymer.

[0026] The PLA polymer can include residual monomer percent. As used herein, “residual monomer percent” refers to the amount of lactic acid and/or lactide monomer that is unreacted yet which remains entrapped within the structure of the entangled PLA polymer chains. In general, if the residual monomer percent of PLA polymer is too high, the polymer blend may be difficult to process due to inconsistent processing properties caused by a large amount of monomer vapor being released during processing that cause variations in extrusion pressures. However, a minor amount of residual monomer in PLA polymer in the blend may be beneficial due to such residual monomer functioning as a plasticizer during a spinning process. The PLA polymer can have a residual monomer percent that is less than about 15 percent, for example less than about 10 percent, and as another example less than about 7 percent, although the present invention is not limited thereto.

[0027] The blend further includes a material that forms a reactive agent or species when exposed to appropriate conditions or stimulus, wherein the reactive agent or species can act upon (react with) the degradable polymer to accelerate degradation thereof. As used herein, reference to accelerating the degradation of the degradable polymer means that the rate of degradation of the polymer is accelerated as compared to the rate of degradation of the same polymer under the same conditions but in the absence of the material forming a reactive agent or species. For example, the material can form a chemical agent capable of accelerating the hydrolysis of PLA, as compared to the rate of hydrolysis of the PLA in the absence of the same.

[0028] The mechanism by which the reactive agent or species is generated is not limited. In exemplary embodiments, the material may generate the reactive agent or species upon exposure of the polymer blend to water, caustic, heat, radiation, and the like, and combinations of such stimuli.

[0029] In exemplary embodiments, the material that upon exposure to appropriate conditions or stimulus can form an agent that accelerates degradation of the degradable polymer is a soy-based material. The soy-based material can be derived from soybeans in accordance with methods generally known in the art. For example, the soy-based material can be a refined soy-based material. As used herein, the term “refined soy-based material” refers to comminuted, ground, crushed, or otherwise divided form of soybean material.

[0030] Generally, the refined soy-based material can be in any form, such as but not limited to chips, pellets, flakes, granules, flour, meal, and the like, and mixtures thereof. In exemplary embodiments, the refined soy-based material can be in the form of soy flour, as known in the art. Generally, soy flour is a finely ground form of soybeans, although the present invention is not limited to any particle size of the soy flour, or other refined soy product.

[0031] Although not wishing to be bound by any explanation of the invention, the soy-based material is currently believe to generate a reactive agent when exposed to water, which agent can react with PLA polymer in the blend to accelerate the rate of hydrolysis of the same.

[0032] The amount of the degradable polymer in the blend can vary and can be selected to provide sufficient processability and physical properties to the fiber. Stated differently, the amount of degradable polymer can be selected to provide viable processing of the fiber and to minimize degradation of properties inherent to the polymer, such as fiber strength, elongation, etc. Further, the amount of the material generating the reactive agent or species can be selected to provide sufficient initiation of the degradation process of the degradable polymer so that the degradation rate thereof is accelerated, as compared to the degradation rate of the polymer under the same conditions but without the presence of the material. Accordingly, the weight ratio of the degradable polymer and the material that generates an agent upon exposure to stimulus in the blend can vary.

[0033] In exemplary embodiments, the blend of the degradable polymer and the material that generates an agent upon exposure to stimulus may include the degradable polymer in an amount of about 50 to about 99.99 weight percent, for example about 80 to about 99 wt %, as another example about 90 to about 99 wt %, based on the total weight of the blend.

[0034] In some embodiments, the blend of the degradable polymer and the material that generates an agent upon exposure to stimulus can include the degradable polymer in an amount of about 50, 51, 52, 53, 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69, 70, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80, 81, 82, 83, 84, 85, 86, 87, 88, 89, 90, 91, 92, 93, 94, 95,
waxes, flow promoters, solid solvents, particulates, other materials added to enhance processability of blend, and the like, and combinations thereof. These and other additives can be used in conventional amounts.

The fibers of the invention can be hollow or non-
hollow fibers and further can have a substantially round or circular cross-section or a non-circular cross-section (for example, “shaped fibers” or fibers with shaped cross-
sections, such as but not limited to oval fibers, rectangular fibers, multi-lobed or lobal fibers, delta cross-sections, and the like).

The thermoplastic fibers of the invention can be prepared using conventional fiber processing techniques known in the art. For example, the degradable polymer and the material that generates the chemical agent or species can be blended with one another using conventional mixing techniques. In exemplary embodiments, the polymer blend components can be dry blended with one another prior to melting the polymer blend in subsequent extrusion or other polymer processing steps.

The thermoplastic fibers can be useful in the production of a wide variety of textile materials or structures. As used herein, the textile materials can include without limitation multi-fiber structures such as yarns, as well as nonwoven fabrics, woven fabrics, knit fabrics, and the like, and combinations thereof.

Exemplary nonwoven structures can include without limitation carded webs, wet laid webs, dry laid webs, spunbonded webs, meltblown webs, webs formed by electrospinning, and the like, and combinations thereof. Nonwoven fabrics can be made according to any of the known processes for making nonwoven fabrics, including processes that use mechanical, electrical, pneumatic, and/or hydrodynamic means for forming or assembling fibers into a web, for example carding, wetlaying, air laying, spunbonding, meltblowing, electrospinning, and the like. The webs can be bonded using techniques as known in the art, such as but not limited to mechanical bonding, such as hydroentanglement and needle punching, adhesive bonding, thermal bonding, and the like, to form a coherent and useful fabric structure. An example of thermal bonding is through-air bonding, although other thermal bonding techniques, such as calendaring, microwave or other RF treatments can be used.

Fibers other than the fibers of the invention may also be present in the textile structures, including any of the various synthetic and/or natural fibers known in the art. Exemplary synthetic fibers include without limitation polyolefin fibers, polyester fibers, polyamide fibers, acrylic fibers, rayon fibers, cellulose acetate fibers, and the like and combinations thereof. Exemplary natural fibers include without limitation wool fibers, cotton fibers, wool pulp fibers and the like and combinations thereof.

The present invention further provides articles including the thermoplastic fibers of the invention. Non-
woven fabrics which include the fibers of the invention are particularly suited for use as a component of cigarette fillers. Other examples include without limitation disposable personal care products, wipes, disposable medical products, and the like.

Many modifications and other embodiments of the invention will come to mind to one skilled in the art to which this invention pertains having the benefit of the teachings presented in the foregoing descriptions. Therefore, it is to be understood that the invention is not to be limited to the specific embodiments disclosed and that modifications and other
embodiments are intended to be included within the scope of the appended claims. Although specific terms are employed herein, they are used in a generic and descriptive sense only and not for purposes of limitation, the scope of the invention being defined in the claims.

That which is claimed is:

1. A thermoplastic fiber comprising a blend, wherein the blend comprises a degradable polymer and a material that generates an agent upon exposure to stimulus that accelerates degradation of the degradable polymer.

2. The thermoplastic fiber of claim 1, wherein the degradable polymer comprises a biodegradable polymer.

3. The thermoplastic fiber of claim 2, wherein the biodegradable polymer comprises polyvinyl alcohol, hydrolyzable aliphatic polyester, hydrolyzable aliphatic polyurethane, cis-polyisoprene, cis-polybutadiene, poly(caprolactone), poly(lactic acid) polymer, polyhydroxyalkanoate (PHA), a copolymer thereof, or a blend thereof

4. The thermoplastic fiber of claim 1, wherein the degradable polymer comprises poly(lactic acid) polymer.

5. The thermoplastic fiber of claim 1, wherein the material comprises a soy-based material.

6. The thermoplastic fiber of claim 5, wherein the soy-based material comprises a refined soy-based material.

7. The thermoplastic fiber of claim 6, wherein the refined soy-based material comprises soy flour.

8. The thermoplastic fiber of claim 1, wherein the agent accelerates hydrolysis of the degradable polymer.

9. The thermoplastic fiber of claim 1, wherein the material generates the agent upon exposure to water, caustic, heat, radiation, or a combination thereof

10. The thermoplastic fiber of claim 1, wherein the material generates the agent upon exposure to water.

11. The thermoplastic fiber of claim 1, comprising a continuous filament, spunbonded filament, staple fiber, meltblown fiber, nanofiber, nanofilament, or a combination thereof.

12. The thermoplastic fiber of claim 1, wherein the blend comprises the degradable polymer and the material that generates an agent upon exposure to stimulus in a weight ratio of about 50:50 to about 99:1.

13. The thermoplastic fiber of claim 12, wherein the blend comprises the degradable polymer and the material that generates an agent upon exposure to stimulus in a weight ratio of about 90:10 to about 99:1.

14. A textile structure comprising a thermoplastic fiber comprising a blend, wherein the blend comprises a degradable polymer and a material that generates an agent upon exposure to stimulus that accelerates degradation of the degradable polymer.

15. The textile structure of claim 14, comprising a non-woven web, a knit web, a woven web, or a combination thereof.

16. The textile structure of claim 14, comprising a non-woven web.

17. The textile structure of claim 16, wherein the nonwoven web comprises a spunbonded web, a meltblown web, a web including staple fibers, a web formed by electrospinning, or a combination thereof.

18. An article comprising a textile structure formed using a thermoplastic fiber comprising a blend, wherein the blend comprises a degradable polymer and a material that generates an agent upon exposure to stimulus that accelerates degradation of the degradable polymer.

19. The article of claim 18, comprising a cigarette component.

20. The article of claim 19, comprising a cigarette filter.

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