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(54) ARTIFICIAL TURF WITH IMPROVED TUFT-LOCK

(57) Embodiments of the present disclosure are directed to artificial turf filaments comprising a non-functionalized polyolefin and at least one functionalized polymer. The functionalized polymer is a propylene-based polymer having one or more functional groups grafted on the propylene-based polymer. The one or more functional groups is selected from the group consisting of amine groups and imide groups. The at least one functionalized polymer has a DSC melting point from 100 °C to 130 °C. When the stretched filament is stretched to a stretch ratio of 5, the stretched filament has a tenacity greater than 0.90 cN/dtex.

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Description

Field

[0001] Embodiments of the present disclosure generally relate to artificial turf filaments, articles incorporating artificial turf filaments, and their manufacture.

Background

[0002] Synthetic or artificial turfs are increasingly being used as an alternative to natural grass turf for use on sport athletic fields, playgrounds, landscaping, and in other leisure applications. To produce an artificial turf, turf yarns may be extruded, and then tufted through a primary backing. A secondary backing may be applied to "glue" the turf yarn to the primary backing.

[0003] During the lifetime of the artificial turf, the yarn and backing are subjected to continuous stresses. The durability of the artificial turf depends in large part on the adhesion between the yarn and the backing. For example, if the adhesion between the yarn and the backing are poor, the yarn filaments are pulled off the backing as a result of the stresses, which may leave areas of the artificial turf without yarn.

[0004] Accordingly, alternative artificial turf yarns and/or artificial turfs having improved adhesion between the yarn and the backing are desired.

Summary

[0005] Disclosed in embodiments herein are stretched filaments. The stretched filaments comprise a blend of at least one functionalized polymer and a non-functionalized polyolefin. The functionalized polymer is a propylene-based polymer having one or more functional groups grafted thereon and having a Differential Scanning Calorimetry (DSC) melting point from 100 °C to 130 °C. The one or more functional groups are selected from the group consisting of amine groups and imide groups. When the stretched filament is stretched to a stretch ratio of 5, the stretched filament has a tenacity greater than 0.90 cN/dtex. Various embodiments described herein exhibit improved adhesion between the stretched filament and the polyurethane backing, as will be described in greater detail hereinbelow. Without being bound by theory, it is believed that the functionalized polymer enhances the polarity, thus increasing the adhesion of the filament to the polyurethane backing.

[0006] Even further disclosed in embodiments herein are artificial turfs. The artificial turfs comprise a primary backing, a secondary backing, and at least one stretched filament. The stretched filaments comprise a blend of at least one functionalized polymer and a non-functionalized polyolefin. The functionalized polymer is a propylene-based polymer having one or more functional groups grafted thereon and having a DSC melting point from 100 °C to 130 °C. The one or more functional groups is selected from the group consisting of amine groups and imide groups. When the stretched filament is stretched to a stretch ratio of 5, the stretched filament has a tenacity greater than 0.90 cN/dtex.

[0007] Additional features and advantages of the embodiments will be set forth in the detailed description which follows, and in part will be readily apparent to those skilled in the art from that description or recognized by practicing the embodiments described herein, including the detailed description which follows, the claims, as well as the appended drawings.

[0008] It is to be understood that both the foregoing and the following description describe various embodiments and are intended to provide an overview or framework for understanding the nature and character of the claimed subject matter. The accompanying drawings are included to provide a further understanding of the various embodiments, and are incorporated into and constitute a part of this specification. The drawings illustrate the various embodiments described herein, and together with the description serve to explain the principles and operations of the claimed subject matter.

Brief description of the drawings

[0009]

FIG. 1A pictorially depicts an exemplary monofilament extrusion line that may be used to produce the artificial turf filaments according to one or more embodiments shown and described herein;

FIG. 1B pictorially depicts an exemplary Collins fiber spinning line that may be used to produce the artificial turf filaments according to one or more embodiments shown and described herein; and

FIG. 2 pictorially depicts a cutaway view of an artificial turf according to one or more embodiments shown and described herein.

Detailed description

[0010] Reference will now be made in detail to embodiments of artificial turf filaments and artificial turfs incorporating artificial turf filaments, characteristics of which are illustrated in the accompanying drawings. As used herein, "filament" refers to monofilaments, multifilaments, extruded films, fibers, yarns, such as, for example, tape yarns, fibrillated tape yarn, slit-film yarn, continuous ribbon, and/or other fibrous materials used to form synthetic grass blades or strands of an artificial turf field.

Artificial Turf Filaments

[0011] The artificial turf filaments described herein comprise at least one functionalized polymer and a non-functionalized polyolefin. In various embodiments, the functionalized polymer is a propylene-based polymer having one or more functional groups grafted thereon. The functional groups may be, for example, an amine group or an imide group. The functionalized polymer has a DSC melting point from 100 °C to 130 °C. When the artificial turf filament is stretched to a stretch ratio of 5, the artificial turf filament has a tenacity of greater than 0.9 cN/dtex.

Non-functionalized Polyolefin

[0012] The non-functionalized polyolefin may include, by way of example and not limitation, non-functionalized ethylene- or propylene-based polymers. As used herein, the term "non-functionalized polyolefin" refers to a polyolefin that is free of grafted moieties. The term "ethylene-based polymer" refers to a polymer that contains more than 50 weight percent polymerized ethylene monomer (based on the total amount of polymerizable monomers) and, optionally, may contain at least one comonomer. The comonomer content may be measured using any suitable technique, such as techniques based on nuclear magnetic resonance ("NMR") spectroscopy, and, for example, by ^{13}C NMR analysis as described in U.S. Patent 7,498,282, which is incorporated herein by reference.

[0013] Suitable ethylene-based polymers may include ethylene homopolymers, copolymers of ethylene and at least one comonomer, and blends thereof. As used herein, the term "copolymer" includes polymers made up of two or more different monomers, including trimers, tetramers, and the like. In various embodiments, the ethylene-based polymer comprises greater than 50 wt.% of the units derived from ethylene and less than 30 wt.% of the units derived from one or more alpha-olefin comonomers. In some embodiments, the ethylene-based polymer comprises (a) greater than or equal to 55%, for example, greater than or equal to 60%, greater than or equal to 65%, greater than or equal to 70%, greater than or equal to 75%, greater than or equal to 80%, greater than or equal to 85%, greater than or equal to 90%, greater than or equal to 92%, greater than or equal to 95%, greater than or equal to 97%, greater than or equal to 98%, greater than or equal to 99%, greater than or equal to 99.5%, from greater than 50% to 99%, from greater than 50% to 97%, from greater than 50% to 94%, from greater than 50% to 90%, from 70% to 99.5%, from 70% to 99%, from 70% to 97% from 70% to 94%, from 80% to 99.5%, from 80% to 99%, from 80% to 97%, from 80% to 94%, from 80% to 90%, from 85% to 99.5%, from 85% to 99%, from 85% to 97%, from 88% to 99.9%, 88% to 99.7%, from 88% to 99.5%, from 88% to 99%, from 88% to 98%, from 88% to 97%, from 88% to 95%, from 88% to 94%, from 90% to 99.9%, from 90% to 99.5% from 90% to 99%, from 90% to 97%, from 90% to 95%, from 93% to 99.9%, from 93% to 99.5% from 93% to 99%, or from 93% to 97%, by weight, of the units derived from the ethylene monomer; and (b) optionally, less than 30 percent, for example, less than 25 percent, or less than 20 percent, less than 18%, less than 15%, less than 12%, less than 10%, less than 8%, less than 5%, less than 4%, less than 3%, less than 2%, less than 1%, from 0.1 to 20 %, from 0.1 to 15 %, 0.1 to 12%, 0.1 to 10%, 0.1 to 8%, 0.1 to 5%, 0.1 to 3%, 0.1 to 2%, 0.5 to 12%, 0.5 to 10%, 0.5 to 8%, 0.5 to 5%, 0.5 to 3%, 0.5 to 2.5%, 1 to 10%, 1 to 8%, 1 to 5%, 1 to 3%, 2 to 10%, 2 to 8%, 2 to 5%, 3.5 to 12%, 3.5 to 10%, 3.5 to 8%, 3.5% to 7%, or 4 to 12%, 4 to 10%, 4 to 8%, or 4 to 7%, by weight, of units derived from one or more alpha-olefin comonomers.

[0014] Suitable comonomers may include alpha-olefin comonomers, typically having no more than 20 carbon atoms. The one or more alpha-olefins may be selected from the group consisting of C_3-C_{20} acetylenically unsaturated monomers and C_4-C_{18} diolefins. Those skilled in the art will understand that the selected monomers are desirably those that do not destroy conventional Ziegler-Natta catalysts. For example, the alpha-olefin comonomers may have 3 to 10 carbon atoms, or 3 to 8 carbon atoms. Exemplary alpha-olefin comonomers include, but are not limited to, propylene, 1-butene, 1-pentene, 1-hexene, 1-heptene, 1-octene, 1-nonene, 1-decene, and 4-methyl-1-pentene. The one or more alpha-olefin comonomers may, for example, be selected from the group consisting of propylene, 1-butene, 1-hexene, and 1-octene; or in the alternative, from the group consisting of 1-butene, 1-hexene and 1-octene. In some embodiments, the ethylene-based polymer comprises greater than 0 wt.% and less than 30 wt.% of units derived from one or more of octene, hexene, or butene comonomers.

[0015] The ethylene-based polymer may be made according to any suitable polymerization process, including but not limited to solution, slurry, or gas phase polymerization processes in the presence of a metallocene, constrained geometry catalyst systems, Ziegler-Natta catalysts, or bisphenyl phenol catalyst systems. The solution, slurry, or gas phase polymerization may occur in a single reactor, or alternatively, in a dual reactor system wherein the same product is produced in each of the dual reactors. Information on preparation and use of the multi-metal catalysts are found in commonly owned, copending U.S. Application No. 14/116070, the disclosure of which is incorporated herein by reference in its entirety.

[0016] In embodiments herein, the ethylene-based polymer may be further characterized by one or more of the following properties: melt flow rate (MFR or I_2), melt flow ratio (I_{10}/I_2), or density, as previously described herein. Without being bound by theory, ethylene-based polymers characterized by melt flow rate (MFR/I_2), melt flow ratio (I_{10}/I_2), or density may be particularly well suited for blending with other filament components and/or extruding. For example, polymers with a melt index outside of a particular range may present difficulties in obtaining a homogeneous blend for extrusion. Suitable polymers may include, for example, high density polyethylene (HDPE), linear low density polyethylene (LLDPE), ultra low density polyethylene (ULDPE), homogeneously branched linear ethylene polymers, and homogeneously branched substantially linear ethylene polymers (that is, homogeneously branched long chain branched ethylene polymers). In some embodiments, the ethylene-based polymer is an LLDPE. The LLDPE may include, in polymerized form, a majority weight percent of ethylene based on the total weight of the LLDPE. In an embodiment, the LLDPE is a copolymer of ethylene and at least one ethylenically unsaturated comonomer. In one embodiment, the comonomer is a C_3-C_{20} α-olefin. In another embodiment, the comonomer is a C_3-C_8 α-olefin. In another embodiment, the C_3-C_8 α-olefin is selected from propylene, 1-butene, 1-hexene, or 1-octene. In an embodiment, the LLDPE is selected from the following copolymers: ethylene/propylene copolymer, ethylene/butene copolymer, ethylene/hexene copolymer, and ethylene/octene copolymer. In a further embodiment, the LLDPE is an ethylene/octene copolymer. Commercial examples of suitable ethylene-based copolymers include those sold under the trade names ATTANETM, AFFINITYTM, DOWLEXTM, ELITETM, ELITETM AT, and INNATETM all available from The Dow Chemical Company (Midland, MI); LUMICENE® available from Total SA; and EXCEEDTM and EXACTTM available from Exxon Chemical Company.

[0017] In embodiments herein, the ethylene-based polymer may have a density of 0.900 g/cc to 0.950 g/cc. All individual values and subranges of at least 0.900 g/cc to 0.950 g/cc are included and disclosed herein. For example, in some embodiments, the polyethylene has a density of 0.900 to 0.945 g/cc, 0.900 to 0.940 g/cc, 0.900 to 0.935 g/cc, 0.910 g/cc to 0.945 g/cc, 0.910 to 0.940 g/cc, 0.910 to 0.935 g/cc, 0.910 to 0.930 g/cc, 0.915 to 0.940 g/cc, 0.915 to 0.923 g/cc, or 0.920 g/cc to 0.935 g/cc. Density may be measured in accordance with ASTM D792.

[0018] In embodiments herein, the ethylene-based polymer may have a melt flow rate (MFR), I_2, measured at 190 °C and 2.16 kg of 0.1 g/10 min to 10 g/10 min. All individual values and subranges of at least 0.1 g/10 min to 10 g/10 min are included and disclosed herein. For example, in some embodiments, the ethylene-based polymer may have a melt flow rate (MFR), I_2, of 0.1 g/10 min to 9.5 g/10 min, 0.1 g/10 min to 9.0 g/10 min, 0.1 g/10 min to 5 g/10 min, 0.5 g/10 min to 6 g/10 min, 1 g/10 min to 5 g/10 min, 1.5 g/10 min to 4.5 g/10 min, or 2 g/10 min to 4 g/10 min. In other embodiments, the ethylene-based polymer may have a melt flow rate (MFR), I_2, of 0.7 g/10 min to 9.5 g/10 min, 0.7 g/10 min to 8 g/10 min, or 0.7 g/10 min to 5 g/10 min. Melt flow rate (MFR), I_2, may be measured in accordance with ASTM D1238 (190 °C and 2.16 kg).

[0019] In embodiments herein, the ethylene-based polymer may have a melt flow ratio, I_{10}/I_2, of less than 14. All individual values and subranges of less than 14 are included and disclosed herein. For example, in some embodiments, the ethylene-based polymer may have a melt flow ratio, I_{10}/I_2, of less than 13.5, 13, 12.5, 10, or even 7.5. In other embodiments, the ethylene-based polymer may have a melt flow ratio, I_{10}/I_2, of from 1.0 to 14, 2 to 14, 4 to 14, 5 to 14, 5.5 to 14, 6 to 14, 5 to 13.5, 5 to 13, 5 to 12.5, 5 to 12, 5 to 11.5, 5 to 11, 5.5 to 13.5, 5.5 to 13, 5.5 to 12.5, 5.5 to 12, 5.5 to 11.5, 5.5 to 11, 6 to 13.5, 6 to 13, 6 to 12.5, 6 to 12, 6 to 11.5, or 6 to 11. Melt index, I_{10}, may be measured in accordance with ASTM D1238 (190 °C and 10.0 kg).

[0020] In other embodiments, the non-functionalized polyolefin include propylene-based polymers. The term "propylene-based polymer" refers to a polymer that contains more than 50 weight percent polymerized propylene monomer (based on the total amount of polymerizable monomers) and, optionally, may contain at least one comonomer. Suitable propylene-based polymers may include propylene homopolymers, copolymers of propylene and at least one comonomer, and blends thereof.

[0021] In various embodiments, the propylene-based polymer comprises greater than 50 wt.% of the units derived from propylene and less than 30 wt.% of the units derived from one or more alpha-olefin comonomers. In some embodiments, the propylene-based polymer comprises (a) greater than or equal to 55%, for example, greater than or equal to 60%, greater than or equal to 65%, greater than or equal to 70%, greater than or equal to 75%, greater than or equal to 80%, greater than or equal to 85%, greater than or equal to 90%, greater than or equal to 92%, greater than or equal to 95%, greater than or equal to 97%, greater than or equal to 98%, greater than or equal to 99%, greater than or equal to 99.5%, from greater than 50% to 99%, from greater than 50% to 97%, from greater than 50% to 94%, from greater than 50% to 90%, from 70% to 99.5%, from 70% to 99%, from 70% to 97% from 70% to 94%, from 80% to 99.5%, from

80% to 99%, from 80% to 97%, from 80% to 94%, from 80% to 90%, from 85% to 99.5%, from 85% to 99%, from 85% to 97%, from 88% to 99.9%, 88% to 99.7%, from 88% to 99.5%, from 88% to 99%, from 88% to 98%, from 88% to 97%, from 88% to 95%, from 88% to 94%, from 90% to 99.9%, from 90% to 99.5% from 90% to 99%, from 90% to 97%, from 90% to 95%, from 93% to 99.9%, from 93% to 99.5% from 93% to 99%, or from 93% to 97%, by weight, of the units derived from propylene; and (b) optionally, less than 30 percent, for example, less than 25 percent, or less than 20 percent, less than 18%, less than 15%, less than 12%, less than 10%, less than 8%, less than 5%, less than 4%, less than 3%, less than 2%, less than 1%, from 0.1 to 20 %, from 0.1 to 15 %, 0.1 to 12%, 0.1 to 10%, 0.1 to 8%, 0.1 to 5%, 0.1 to 3%, 0.1 to 2%, 0.5 to 12%, 0.5 to 10%, 0.5 to 8%, 0.5 to 5%, 0.5 to 3%, 0.5 to 2.5%, 1 to 10%, 1 to 8%, 1 to 5%, 1 to 3%, 2 to 10%, 2 to 8%, 2 to 5%, 3.5 to 12%, 3.5 to 10%, 3.5 to 8%, 3.5% to 7%, or 4 to 12%, 4 to 10%, 4 to 8%, or 4 to 7%, by weight, of units derived from one or more alpha-olefin comonomers.

[0022] Suitable comonomers may include ethylene or alpha-olefin comonomers, typically having no more than 20 carbon atoms. The one or more alpha-olefins may be selected from the group consisting of C_4-C_{20} acetylenically unsaturated monomers and C_4-C_{18} diolefins. Those skilled in the art will understand that the selected monomers are desirably those that do not destroy conventional Ziegler-Natta catalysts. For example, the alpha-olefin comonomers may have 2 carbon atoms, 4 to 20 carbon atoms, or 4 to 8 carbon atoms. Exemplary alpha-olefin comonomers include, but are not limited to, 1-butene, 1-pentene, 1-hexene, 1-heptene, 1-octene, 1-nonene, 1-decene, and 4-methyl-1-pentene. The one or more alpha-olefin comonomers may, for example, be selected from the group consisting of 1-butene, 1-hexene, and 1-octene. In some embodiments, the propylene-based polymer comprises greater than 0 wt.% and less than 30 wt.% of units derived from one or more of octene, hexene, or butene comonomers.

[0023] The propylene-based polymer may be made according to any suitable polymerization process, including but not limited to solution, slurry, or gas phase processes in the presence of a metallocene, constrained geometry catalyst systems, Ziegler-Natta catalysts, or bisphenyl phenol catalyst systems. The solution, slurry, or gas phase polymerization may occur in a single reactor, or alternatively, in a dual reactor system wherein the same product is produced in each of the dual reactors. Information on preparation and use of the multi-metal catalysts are found in commonly owned, copending U.S. Application No. 14/116070, the disclosure of which is incorporated herein by reference in its entirety.

[0024] In embodiments herein, the propylene-based polymer may be further characterized by one or more of the following properties: melt flow rate (MFR), melt flow ratio (I_{10}/I_2), or density, as previously described herein.

[0025] In embodiments herein, the propylene based polymer may have a density of from about 0.890 g/cc to about 0.910 g/cc to 0.950 g/cc. All individual values and subranges of at least 0.890 g/cc to 0.950 g/cc are included and disclosed herein. For example, in some embodiments, the polyethylene has a density of 0.890 to 0.905 g/cc, 0.890 to 0.900 g/cc, 0.890 to 0.895 g/cc, 0.895 g/cc to 0.910 g/cc, 0.900 to 0.910 g/cc, or 0.905 to 0.910 g/cc. Density may be measured in accordance with ASTM D792.

[0026] In embodiments herein, the propylene-based polymer may have a melt flow rate, MFR, of 0.5 g/10 min to 25 g/10 min when measured at 230 °C and 2.16 kg. All individual values and subranges of at least 0.5 g/10 min to 25 g/10 min are included and disclosed herein. For example, in some embodiments, the propylene-based polymer may have a melt flow rate, MFR, of 0.5 g/10 min to 22.5 g/10 min, 0.5 g/10 min to 20 g/10 min, 0.5 g/10 min to 15 g/10 min, 0.5 g/10 min to 10 g/10 min, 1 g/10 min to 10 g/10 min, 1.5 g/10 min to 10 g/10 min, or 3 g/10 min to 10 g/10 min. In one embodiment, the propylene-based polymer may have a melt flow rate of 2.0 g/10 min to 4.0 g/10 min when measured at 230 °C and 2.16 kg. Melt flow rate, MFR, may be measured in accordance with ASTM D 1238 (230 °C and 2.16 kg).

[0027] In embodiments herein, the propylene-based polymer may have a melt flow ratio, I_{10}/I_2, of less than 10. All individual values and subranges of less than 10 are included and disclosed herein. For example, in some embodiments, the propylene-based polymer may have a melt flow ratio, I_{10}/I_2, of less than 10, 9, or even 7. In other embodiments, the propylene-based polymer may have a melt flow ratio, I_{10}/I_2, of from 1.0 to 10, 2 to 9, or 3 to 7.

Functionalized Polymer

[0028] As stated above, the artificial turf filaments described herein further include at least one functionalized polymer. In various embodiments, the functionalized polymer is a propylene-based polymer having one or more functional groups grafted thereon. In one embodiment, the at least one functionalized polymer is a polymer formed from a propylene and at least one organic compound selected from an "amine-containing compound" or an "imide-containing compound." As used herein, the term "amine-containing compound" refers to a chemical compound comprising at least one amine group. As used herein, the term "imide-containing compound" refers to a chemical compound comprising at least one imide group.

[0029] In embodiments, the at least one functionalized propylene-based polymer is a propylene/ethylene copolymer or a propylene/alpha-olefin copolymer. In another embodiment, the propylene-base polymer is a propylene/alpha-olefin copolymer wherein the alpha-olefin is a C_4-C_{20} alpha-olefin, or a C_4-C_{10} alpha-olefin. In another embodiment, the alpha-olefin is selected from the group consisting of 1-butene, 1-hexene, and 1-octene. In another embodiment, the propylene/alpha-olefin copolymer has a density from 0.850 g/cc to 0.930 g/cc. In another embodiment, the propylene/alpha-olefin copolymer has a density from 0.870 g/cc to 0.930 g/cc. In another embodiment, the propylene/alpha-olefin copolymer has a melt flow rate MFR (I_2), measured at 230 °C and 2.16 kg, from 1 g/10 min to 20 g/10 min.

[0030] In another embodiment, the propylene-based polymer is a propylene/ethylene copolymer. In a further embodiment, the propylene/ethylene copolymer has a density from 0.850 g/cc to 0.930 g/cc, or from 0.870 g/cc to 0.930 g/cc. In another embodiment, the propylene/ethylene copolymer has a melt flow rate MFR (I_2), measured at 230 °C and 2.16 kg, from 1 g/10 min to 20 g/10 min. In embodiments herein, the propylene/ethylene copolymer has an ethylene content of less than about 5 wt.%. In another embodiment, the propylene/ethylene copolymer has an ethylene content of less than about 4 wt.%. For example, the propylene/ethylene copolymer may have an ethylene content of greater than about 0 wt.% to about 5 wt.%, including all individual values and subranges from greater than about 0 wt.% to about 5 wt.%.

[0031] In various embodiments, the at least one functionalized propylene-based polymer has a differential scanning calorimetry (DSC) melting point from about 100 °C to about 130 °C or from about 110 °C to about 120 °C. The functionalized propylene-based polymer of various embodiments has a percent crystallinity of less than or equal to 30%, or less than or equal to 25%, or less than or equal to 22.5%, as measured by DSC. In some embodiments, the functionalized propylene-based polymer has a percent crystallinity of from about 10% to about 30%, as measured by DSC, including all individual values and subranges from 10 % to 30%. Suitable propylene-based polymers may include, by way of example and not limitation, VERSIFY™ 3000, commercially available from The Dow Chemical Company (Midland, MI).

Methods of Making Functionalized Polymers

[0032] In various embodiments, the at least one functionalized propylene-based polymer is formed by grafting an "amine-reactive" group onto a propylene-based polymer to form a grafted propylene-based polymer and then reacting the grafted propylene-based polymer with an "amine-containing compound" or "imide-containing compound."

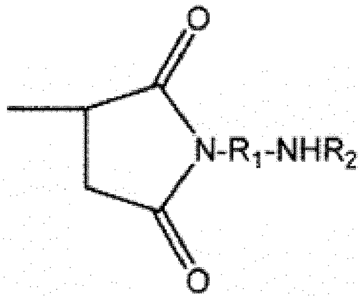
[0033] For example, in an embodiment, the at least one functionalized propylene-based polymer is formed from a process comprising the following steps: 1) grafting onto the backbone of a propylene-based polymer at least one compound comprising at least one "amine-reactive" group to form a grafted propylene-based polymer; 2) reacting a primary-secondary diamine with the grafted propylene-based polymer; and 3) wherein step 2) takes place subsequent to step 1), without the isolation of the grafted propylene-based polymer (i.e., removal of the grafted propylene-based polymer from the solution containing the compound containing the amine-reactive group and the propylene-based polymer), and wherein both steps take place in a melt reaction. The term "amine-reactive group," as used, refers to a chemical group or chemical moiety that can react with an amine group. Amine-reactive groups include, but are not limited to, maleic anhydride, acrylic acid, methacrylic acid, glycidyl acrylate, glycidyl methacrylate.

[0034] As used herein, the term "primary-secondary diamine" refers to a diamine made up of a primary amine and a secondary amine. Suitable primary-secondary diamines include compounds of structure (I):

$$H_2N\text{-}R_1\text{-}NH\text{-}R_2 \qquad (I).$$

[0035] In structure (I), R_1 is a divalent hydrocarbon radical, and preferably a linear hydrocarbon of the formula $-(CH_2)_n-$, where n is greater than, or equal to, 2, n is from 2 to 10, from 2 to 8, or even from 2 to 6. R_2 is a monovalent hydrocarbon radical containing at least 2 carbon atoms, and optionally may be substituted with a heteroatom containing group, such as OH or SH. In embodiments, R_2 a linear hydrocarbon of the formula $-(CH_2)_nCH_3$, where n is from 1 to 10, from 1 to 9, from 1 to 7, or even from 1 to 5. In embodiments, the primary-secondary diamine is selected from the group consisting N-ethylethylenediamine, N-phenylethylenediamine, N-phenyl-1,2-phenylene-diamine, N-phenyl-1,4-phenylenediamine, and N-(2-hydroxyethyl)- ethylenediamine.

[0036] In another embodiment, the at least one functionalized propylene-based polymer comprises the following functional group covalently bonded to the propylene-based polymer backbone:



wherein "NR_1NHR_2" may be derived from a primary-secondary diamine selected from the group of compounds of structure (I) below:

$$H_2N\text{-}R_1\text{-}NH\text{-}R_2 \qquad (I),$$

wherein R_1 is a divalent hydrocarbon radical selected from the group consisting of alkylene or phenylene, such as, by way of example and not limitation, $-CH_2CH_2-$, -para-phenylene-, or ortho-phenylene-, and R_2 is a monovalent hydrocarbon radical containing at least 2 carbon atoms, and optionally may be substituted with a heteroatom containing group, such as an alkyl or aryl group. In embodiments, the alkyl or aryl group is an ethyl or a phenyl group.

[0037] In another embodiment, the at least one functionalized propylene-based polymer is formed from a process comprising the following steps: 1) functionalizing the propylene-based polymer with at least one compound comprising at least one "amine-reactive" group to form a grafted propylene-based polymer; 2) blending the grafted propylene-based polymer, in a solid, non-molten form, with at least one primary-secondary diamine; 3) imbibing the primary-secondary diamine into the grafted propylene-based polymer; 4) reacting the primary-secondary diamine with the grafted propylene-based polymer to form an imide functionalized propylene-based polymer. The term "imbibing," and similar terms, as used, refers to the process in which a compound is absorbed into a polymer solid, particle, pellet, or article. More particularly, a polyolefin is first functionalized with a group reactive with amine functionality, such as an anhydride group. At least one diamine is mixed with the functionalized polyolefin at a temperature below the melting point of the polyolefin. In some embodiments, the temperature is room temperature, although other temperatures are contemplated. The diamine is allowed to absorb or imbibe into the polyolefin, and reacts with diamine reactive group to form a succinamic acid. The reaction of the diamine with the diamine reactive functional group to form the imide ring can then be completed by subjecting the mixture to a thermal treatment, such as in a melt extrusion process. The imbibing process helps to ensure that the diamine is thoroughly mixed with the polyolefin for an efficient functionalization reaction.

[0038] In another embodiment, the at least one functionalized propylene-based polymer is formed from a process comprising the following steps: 1) grafting onto the backbone of a propylene-based polymer at least one compound comprising at least one "amine-reactive" group to form a grafted propylene-based polymer; 2) reacting a alkanolamine with the grafted propylene-based polymer; and wherein step 2) takes place subsequent to step 1), without the isolation of the grafted propylene-based polymer, and wherein both steps 1) and 2) take place in a melt reaction.

[0039] In further embodiments, the alkanolamine is selected from the group consisting of 2-aminoethanol, 2-amino-1-propanol, 3-amino-1-propanol, 2-amino-1-butanol, 2-(2-aminoethoxy)-ethanol and 2-aminobenzyl alcohol.

[0040] Without being bound by theory, increased grafting on the polypropylene increases the melt flow rate, I_2, measured at 230 °C and 2.16 kg, of the polymer. Accordingly, in order to maintain a viscosity that is compatible with the viscosity of the non-functionalized polyolefin, in various embodiments, the polypropylene-based polymer has a graft level of from about 0.1 wt.% to about 3.0 wt.%, depending on the particular polyproylene-based polymer employed. The graft level may be determined by Fourier Transform Infrared Spectroscopy (FTIR). Without being bound by theory, compatibility of the melt indices of the polypropylene-based polymer and the non-functionalized polyolefin enables the components of the artificial turf filaments to be suitably blended for extrusion.

[0041] In various embodiments, the artificial turf filaments include from about 1 wt.% to about 30 wt.% of the functionalized polymer, including all individual values and subranges from 1 wt.% to 30 wt.%. Such individual values and subranges are disclosed herein. In another embodiment, the artificial turf filaments include from about 1 wt.% to about 20 wt.% of the functionalized polymer. In yet another embodiment, the artificial turf filaments include from about 5 wt.% to about 20 wt.% of the functionalized polymer. In embodiments described herein, the artificial turf filaments include from about 68 wt.% to about 99 wt.% of the non-functionalized polyolefin, including all individual values and subranges from 68 wt.% to 99 wt.%. In other embodiments, the artificial turf filaments include from about 75 wt.% to about 99 wt.% of the non-functionalized polyolefin, from about 80 wt.% to about 99 wt.% of the non-functionalized polyolefin, or even from about 85 wt.% to about 99 wt.% of the non-functionalized polyolefin.

[0042] In embodiments herein, the artificial turf filaments may further include one or more additives. Nonlimiting examples of suitable additives include antioxidants, pigments, colorants, UV stabilizers, UV absorbers, curing agents, cross linking co-agents, boosters and retardants, processing aids, fillers, coupling agents, ultraviolet absorbers or stabilizers, antistatic agents, nucleating agents, slip agents, plasticizers, lubricants, viscosity control agents, tackifiers, antiblocking agents, surfactants, extender oils, acid scavengers, and metal deactivators. In an embodiment, colorant, such as Sicolen® green 85-125345 (available from BASF), may be added in an amount of less than about 10 wt.%, less than about 8 wt.%, less than about 6 wt.%, or even less than about 4 wt.%. In another embodiment, a processing aid, such as ARX-741 (available from Argus), may be added in an amount of less than about 2 wt.%, less than about 1.5 wt.%, or even less than about 1 wt.%. Additives can be used in amounts ranging from less than about 0.01 wt.% to more than about 10 wt.% based on the weight of the composition.

[0043] In various embodiments, when the artificial turf filament is stretched to a stretch ratio of 5, the artificial turf filament has a tenacity greater than 0.90 cN/dtex or from about 0.9 cN/dtex to about 1.5 cN/dtex. Tenacity is defined as the tensile force at break divided by the linear weight (dtex). The linear weight (in dtex) of a monofilament is equal to the weight of weighing 50 meters of the monofilament. In embodiments, the artificial turf filament may exhibit an elongation of at least 55% or at least 60%. In embodiments, the artificial turf filament may exhibit an elongation of from about 30% to about 150%, from about 90% to about 110%, or from about 95% to about 105%. Elongation, which is the strain at break, is measured according to ISO 188/ASTM E145 on a Zwick tensile tester on a filament length of 250 mm and extension rate of 250 mm/minute until the filament breaks. In embodiments, the tenacity and elongation values may impact the durability of the filaments and, thus, the artificial turf made therefrom.

[0044] In some embodiments herein, the artificial turf filaments may exhibit a shrinkage of less than 20%. Because the artificial turf filaments exhibit low shrinkage, shorter filaments may be used to maintain the final desired yarn length of the artificial turf. All individual values and subranges of less than 20% are included and disclosed herein. For example, in some embodiments, the artificial turf filaments may exhibit a shrinkage lower than 19%, lower than 18%, lower than 15% or lower than 14%. The shrinkage may be determined by submerging 1 meter of yarn in a heated oil bath at 90 °C for 20 seconds.

Process for Making Artificial Turf Filaments

[0045] The artificial turf filaments described herein may be made using any appropriate process for the production of artificial turf filament from polymer compositions as the artificial turf filaments described herein are process independent. In some embodiments, a method of manufacturing an artificial turf filament comprises providing a blend of a non-functionalized polyolefin and a functionalized propylene-based polymer as previously described herein, and extruding the blend of the non-functionalized polyolefin and the functionalized propylene-based polymer into an artificial turf filament. The artificial turf filament may be extruded to a specified width, thickness, and/or cross-sectional shape depending on the physical dimensions of the extruder. As mentioned above, the artificial turf filament can include a monofilament, a multifilament, a film, a fiber, a yarn, such as, for example, tape yarn, fibrillated tape yarn, or slit-film yarn, a continuous ribbon, and/or other fibrous materials used to form synthetic grass blades or strands of an artificial turf field.

[0046] Referring to FIGS. 1A and 1B, the following describes one such exemplary process 100 that may be used to make artificial turf filaments. In process 100, artificial turf filaments are made by extrusion. For example, the non-functionalized polyolefin and the functionalized propylene-based polymer may be blended together along with any additives to form an extrusion mixture. Suitable artificial turf filament extruders may be equipped with a single polyethylene/polypropylene general purpose screw and a melt pump ("gear pump" or "melt pump") to precisely control the consistency of polymer volume flow into the die 105, as shown in FIGS. 1A and 1B. Artificial turf filament dies 105 may have multiple single holes for the individual filaments distributed over a circular or rectangular spinplate. The shape of the holes corresponds to the desired filament cross-section profile, including for example, rectangular, dog-bone, and v-shaped. A standard spinplate has 50 to 160 die holes of specific dimensions. Lines can have output rates from 150 kg/h to 350 kg/h.

[0047] The artificial turf filaments 110 may be extruded into a water bath 115 with a die-to-water bath distance of from 16 to 40 mm. Coated guiding bars in the water redirect the filaments 110 towards the first takeoff set of rollers 120. The linear speed of this first takeoff set of rollers 120 may vary from 15 to 70 m/min. The first takeoff set of rollers 120 can be heated and used to preheat the filaments 110 after the waterbath 115 and before entering the stretching oven 125. The stretching oven 125 may be a heated air or water bath oven. The filaments 110 may be stretched in the stretching oven 125 to a predetermined stretched ratio. In some equipment configurations, the stretching oven 125 is replaced by one or more heated godets 300-310, as shown in FIG. 1B. In some embodiments, the stretch ratio is at least 4. In other embodiments, the stretch ratio is at least 4.5, 4.8, 5.0, 5.2, or 5.5. The stretching ratio is the ratio between the speed of the second takeoff set of rollers 130 after the stretching oven and the speed of the first takeoff set of rollers 120 before the stretching oven (V2/V1 as shown in FIG. 1A). The second takeoff set of rollers 120 may be run at a different (higher or lower) speed than the first set of rollers 130. In embodiments in which stretching is performed over heated godets, the stretching ratio is the ratio between the speed of the godet 310 and the speed of the godet 300.

[0048] After the filaments 110 are passed over the second takeoff set of rollers 130, they are then drawn through a set of three annealing ovens 135, 140, and 145. The three annealing ovens 135, 140, and 145 may be either a hot air oven with co- or countercurrent hot air flow, which can be operated from 50 °C to 150 °C or a hot water-oven, wherein the filaments 110 are oriented at temperatures from 50 °C to 98 °C. At the exit of the first annealing oven 135, the filaments 110 are passed onto a third set of rollers 150 that may be run at a different (higher or lower) speed than the second set of rollers 130. The linear velocity ratio of the third set of rollers 150 located after the oven to the second set of rollers 130 located in front of the oven may be referred to as either a stretching or relaxation ratio. At the exit of the second annealing oven 140, the filaments 110 are passed onto a fourth set of rollers 155 that may be run at a different

[0049] (higher or lower) speed than the third set of rollers 150. At the exit of the third annealing oven 145, the filaments 110 are passed onto a fifth set of rollers 160 that may be run at a different (higher or lower) speed than the fourth set of rollers 155. In some embodiments, the annealing ovens 135, 140, and 145 may be replaced with heated godets 320 and 330, as depicted in FIG. 1B.

[0050] The artificial turf filament may optionally undergo further post-extrusion processing (e.g., annealing, cutting, etc.).

Artificial Turf

[0051] One or more embodiments of the artificial turf filaments described herein may be used to form an artificial turf field. Referring to FIG. 2, depicted is a cutaway view of an artificial turf field 200 according to one or more embodiments shown and/or described herein. The artificial turf field 200 comprises a primary backing 205 having a top side 210 and a bottom side 215; and at least one artificial turf filament 220 as previously described herein. The at least one artificial turf filament 220 is affixed to the primary backing 205 such that the at least one artificial turf filament 220 provides a tufted face 225 extending outwardly from the top side 210 of the primary backing 205. As used herein, "affix," "affixed," or "affixing" includes, but is not limited to, coupling, attaching, connecting, fastening, joining, linking or securing one object to another object through a direct or indirect relationship. The tufted face 225 extends from the top side 210 of the primary backing 205, and can have a cut pile design, where the artificial turf filament loops may be cut, either during tufting or after, to produce a pile of single artificial turf filament ends instead of loops.

[0052] The primary backing 205 can include, but is not limited to, woven, knitted, or nonwoven fibrous webs or fabrics made of one or more natural or synthetic fibers or yams, such as polypropylene, polyethylene, polyamides, polyesters, and rayon. The artificial turf field 200 may further comprise a secondary backing 230 bonded to at least a portion of the bottom side 215 of the primary backing 205 such that the at least one artificial turf filament 220 is affixed in place to the bottom side 215 of the primary backing 205. The secondary backing 230 may comprise polyurethane (including, for example, polyurethane supplied under the name ENFORCER™ or ENHANCER™ available from The Dow Chemical Company (Midland, MI)) or latex-based materials, such as, styrene-butadiene latex, or acrylates.

[0053] The primary backing 205 and/or secondary backing 230 may have apertures through which moisture can pass. The apertures may be generally annular in configuration and are spread throughout the primary backing 205 and/or secondary backing 230. Of course, it should be understood that there may be any number of apertures, and the size, shape and location of the apertures may vary depending on the desired features of the artificial turf field 200.

[0054] The artificial turf field 200 may be manufactured by providing at least one artificial turf filament 220 as described herein and affixing the at least one artificial turf filament 220 to a primary backing 205 such that that at least one artificial turf filament 220 provides a tufted face 225 extending outwardly from a top side 210 of the primary backing 205. The artificial turf field 200 may further be manufactured by bonding a secondary backing 230 to at least a portion of the bottom side 215 of the primary backing 205 such that the at least one artificial turf filament 220 is affixed in place to the bottom side 215 of the primary backing 205.

[0055] The artificial turf field 200 may optionally comprise a shock absorption layer underneath the secondary backing 230 of the artificial turf field. The shock absorption layer (not shown) can be made from polyurethane, PVC foam plastic or polyurethane foam plastic, a rubber, a closed-cell crosslinked polyethylene foam, a polyurethane underpad having voids, elastomer foams of polyvinyl chloride, polyethylene, polyurethane, and polypropylene. Non-limiting examples of a shock absorption layer are DOW® ENFORCER™ Sport Polyurethane Systems, and DOW® ENHANCER™ Sport Polyurethane Systems, both available from The Dow Chemical Company (Midland, MI).

[0056] The artificial turf field 200 may optionally comprise an infill material. Suitable infill materials include, but are not limited to, mixtures of granulated rubber particles like SBR (styrene butadiene rubber) recycled from car tires, EPDM (ethylene-propylene-diene monomer), other vulcanized rubbers or rubber recycled from belts, thermoplastic elastomers (TPEs) and thermoplastic vulcanizates (TPVs).

[0057] The artificial turf field 200 may optionally comprise a drainage system. The drainage system allows water to be removed from the artificial turf field and prevents the field from becoming saturated with water. Nonlimiting examples of drainage systems include stone-based drainage systems, EXCELDRAIN™ Sheet 100, EXCELDRAIN™ Sheet 200, AND EXCELDRAIN™ EX-T STRIP (available from American Wick Drain Corp., Monroe, N.C.).

[0058] The embodiments described herein may be further illustrated by the following nonlimiting examples.

Test methods

Density

[0059] Density is measured according to ASTM D792.

Melt Flow Rate and Melt Index

[0060] Melt flow rate (MFR), or I_2, is measured according to ASTM D1238. For ethylene-based polymers, MFR is measured at 190 °C and 2.16 kg. For propylene-based polymers, MFR is measured at 230 °C and 2.16 kg. Melt index, or I_{10}, is measured in accordance with ASTM D1238 at 190 °C and 10 kg.

Basis weight

[0061] The basis weight of filaments is typically reported in the industry by the dtex value. The dtex of a monofilament is equal to the weight in grams of 10 km of the monofilament.

Tensile Strength

[0062] The tensile strength of filaments is measured on according to ISO 527.

Elongation

[0063] Elongation was measured according to ISO 527.

Shrinkage

[0064] The shrinkage of a monofilament (expressed as the percentage reduction in length of a 1 meter sample of the monofilament) is measured by immersing the monofilament for 20 seconds in a bath of silicon oil maintained at 90 °C. Shrinkage is then calculated as: (length before - length after)/length before *100%.

Tenacity

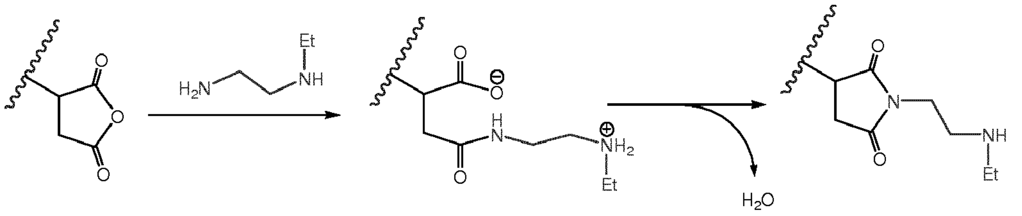
[0065] Tenacity is determined using a Zwick tensile tester, operating on a 260 mm length of the monofilament, and using an extension speed of 250 mm/minute until the filament breaks. The tenacity (in cN/dtex) is the tensile stress (in cN) at break divided by the linear weight (in dtex). The linear weight (in dtex) of a monofilament is equal to the weight of weighing 50 meters of the monofilament.

Examples

[0066] The following conducted examples illustrate one or more of the features of the artificial turf filaments of the present disclosure. A functionalized polymer was prepared and used to prepare a blend including the functionalized polymer and a non-functionalized polyolefin. The blend was also used to prepare artificial turf filaments. Testing was carried out on the artificial turf filaments.

Functionalized Polymer Preparation

[0067] An imidized polypropylene resin was produced by a two-step process. First, a polypropylene-based polymer was grafted with maleic anhydride (MAH). The MAH-grafted polymer was then further reacted with a diamine. A schematic of the reaction using N-ethylethylendiamine is shown below:



[0068] The grafting experiments were completed on a Coperion 25mm twin-screw reactive extrusion line. The reactive extrusion line had 12 barrel sections and 9 temperature zones. Maleic anhydride was dissolved in methyl ethyl ketone (MEK) solvent, at 50 wt.% maleic anhydride, based on the weight of the solution. The maleic anhydride was added to the MEK in a flask and stirred overnight with a magnetic stirrer bar. The MEK solvent, maleic anydride, and peroxide were injected in Barrel #4 (temperature zone 3) of the extruder. The liquid pump system was an ISCO D1000 positive displacement pump, commercially available as Alltech HPLC pump, model 627.

[0069] VERSIFY™ 3000 propylene-ethylene copolymer with 3.5 wt% ethylene content, available from The Dow Chemical Company (Midland, MI), was added into the extruder using a K-Tron model KCLKT20 twin-screw, loss-in-weight feeder. The feed rate was 15 lb/h at the fixed 200 rpm screw speed.

[0070] Once the MAH graft process was completed, the imidization step was performed using N-ethylethylenediamine (DEDA, CAS 110-72-5). The reaction was run in excess of DEDA to minimize the risk of cross-linking and push the conversion of the reaction to completion. Samples were prepared using a 2.5 : 1 molar ratio of primary amine to MAH content.

[0071] The amount of grafting was determined by Fourier Transform Infrared Spectroscopy (FTIR). In particular, 2 g of the grafted polymer was dissolved in 150 mL toluene. The mixture was heated and stirred until all of the grafted polymer was in solution. The solution was cooled for 10 minutes, and 100 mL of cold methane was added to form a precipitate. The solution was suctioned through #2 qualitative filter paper to collect the precipitate. The precipitate was dried in a forced air oven for 1 hour at 100 °C, then pressed into a film. The film was then processed using an FTIR spectrometer.

[0072] Non-functionalized VERSIFY™ 3000 was used for the comparative polymer.

[0073] Table 1 provides selected properties of the functionalized propylene-based polymer and comparative propylene-based polymer.

Table 1

Polymer	Density (g/cc)	MFR (I_2) (g/10 min)	DSC Melting Point	DSC Crystallinity	Grafted level (wt%)
Comparative Propylene-Based Polymer (VERSIFY™ 3000)	0.891	8.0	108 °C	38%	0
Functionalized Propylene-Based Polymer	0.898	7.2	116 °C	20.8%	0.5

Polymer Blend

[0074] A blend including a functionalized polymer and a non-functionalized polyolefin was prepared from the functionalized propylene-based polymer in Table 1. Various examples and comparative examples (Examples 1 and 2 and Comparative Examples 1 and 2) included DOWLEX™ 2107, available from The Dow Chemical Company (Midland, MI), as the non-functionalized polyolefin. DOWLEX™ 2107 is a linear low density polyethylene (LLDPE) resin with a density of 0.917 g/cc, as measured according to ASTM D792, melt flow rate (MFR), I_2, of 2.3 g/10 min, measured according to ASTM D1238 at 190 °C, 2.16 kg, and a melt flow ratio, I_{10}/I_2, of from 6 to 14, measured according to ASTM D1238 (190 °C and 10kg). A third example (Example 3) included Braskem D105.02, available from Braskem (Sao Paolo, Brazil), as the non-functionalized polyolefin. Braskem D105.02 is a non-functionalized polypropylene.

[0075] In particular, two examples (Examples 1 and 2) were prepared by mixing DOWLEX™ 2107 with 5% of the functionalized propylene-based polymer in Table 1 and 10% of the functionalized propylene-based polymer in Table 1, respectively. A third example (Example 3) was prepared by mixing Braskem D105.02 with 10% of the functionalized propylene-based polymer in Table 1.

[0076] Two comparative examples were additionally prepared. One comparative example (Comparative Example 1) included only DOWLEX™ 2107. The second comparative example (Comparative Example 2) included DOWLEX™ 2107 and 5% functionalized polyethylene in Table 1.

[0077] Table 2 provides the contents of the various examples in wt.%.

Table 2

	DOWLEX™ 2107 (non-functionalized polyethylene)	Braskem D105.02 (non-functionalized polypropylene)	Functionalized Polyethylene (functionalized ENGAGE™)	Functionalized Polypropylene (Functionalized VERSIFY™ 3000)
Example 1	95	0	0	5
Example 2	90	0	0	10
Example 3	0	90	0	10
Comp. Example 1	100	0	0	0

(continued)

	DOWLEX™ 2107 (non-functionalized polyethylene)	Braskem D105.02 (non-functionalized polypropylene)	Functionalized Polyethylene (functionalized ENGAGE™)	Functionalized Polypropylene (Functionalized VERSIFY™ 3000)
Comp. Example 2	95	0	5	0

Artificial Turf Filament

[0078] The artificial turf filaments were prepared from the examples. The filament formulations are presented as wt.% of the total filament formulation in Table 3 below. The additives, color (color masterbatch BASF Sicolen 85125345) and a processing aid (Argus ARX-741) were blended with the polymer compositions prior to extrusion. Each of the filaments was prepared on a Collins fiber spinning line (See FIG. 1 B) as described herein.

Table 3

	Example 1	Example 2	Example 3	Comp. Ex. 1	Comp. Ex. 2
DOWLEX™ 2107 (non-functionalized polyethylene)	89.3	84.6	0	94	89.3
Braskem D105.02 (non-functionalized polypropylene)	0	0	84.6	0	0
Functionalized Polyethylene (functionalized ENGAGE™)	0	0	0	0	4.7
Functionalized Polypropylene (Functionalized VERSIFY™ 3000)	4.7	9.4	9.4	0	0
color masterbatch BASF Sicolen 85125345	5.0	5.0	5.0	5.0	5.0
Argus ARX-741	1.0	1.0	1.0	1.0	1.0
Total	100	100	100	100	100

[0079] Table 4 provides specific conditions of the equipment used in preparing the filaments.

Table 4

Parameter	Value
Die type	Mexican Hat (total 4 holes)
Extruder Temperature	melt T 220 °C
Distance die-to-water bath (see FIG. 1)	40 mm
Temperature first godet	97 °C
Temperature second, third, and fourth godets	112 °C
Final speed	140 m/min

[0080] The filaments were tested for shrinkage, tenacity, elongation, and adhesion to polyurethane, and the results are shown in Tables 5 and 6. Tenacity and elongation were measured on a Zwick tensile tester on a filament length of 250 mm and extension rate of 250 mm/min until the filament breaks. Tenacity is defined as the tensile force at break divided by the linear weight (dtex). Elongation is the strain at break. Adhesion to polyurethane was measured by according to the following method.

[0081] Samples were prepared by applying a polyurethane (PU) reaction mixture to polyethylene terephthalate (PET) film at a thickness of 0.76 mm using a wet-film applicator. One filament was carefully married to the coating, making an effort to minimize the inclusion of air pockets. The PET/PU/filament sample was placed between two plates of preheated safety glass to maintain sample flatness, then placed in an 85 °C oven for five (5) minutes to cure the PU. Samples were conditioned for seven (7) days to allow the PU to fully cure. For each filament composition, the measurement was repeated six (6) times. The delamination of the filament from the PU was initiated by hand and continued on an Instron tensile tester. The adhesion force was recorded.

Table 5-Filament Results at Stretch Ratio of 5

	Example 1	Example 2	Example 3	Comp. Ex. 1	Comp. Ex. 2
Shrinkage (%)	13.8	11.7	16	12.6	Broke during stretching
Tenacity (cN/dtex)	1.12	1.23	2.05	1.00	
Elongation	60.8	64.2	78.1	51.4	
Adhesion to Polyurethane (PU)	0.29	0.41	0.20	0.12	

Table 6- Filament Results at Stretch Ratio of 3.66

	Example 1	Comp. Ex. 2
Shrinkage (%)	8.0	10.5
Tenacity (cN/dtex)	0.73	0.64
Elongation	83.8	73.7
Adhesion to PU	0.26	0.15

[0082] As shown in Table 5, tenacity, elongation, and adhesion to polyurethane increased with the addition of a functionalized polymer. Additionally, as shown in Tables 5 and 6, filaments including a functionalized propylene-based polymer showed improvement over filaments including a functionalized ethylene-based polymer (Comp. Ex. 2), which broke during stretching.

[0083] Without being bound by theory, it is believed that during functionalization of the propylene-based polymer, the polymer chain is cut, making it easier for split chains to migrate to the surface of the filament and improve adhesion to the polyurethane. However, it is believed that functionalization of polyethylene creates longer branches, thereby resulting in the opposite effect. It is further believed that the longer branches and crosslinking that occur upon functionalization of polyethylene adversely impact the orientation of the filament, preventing the filament from being stretched to a stretch ratio of 5 and achieving the desired tenacity.

[0084] The dimensions and values disclosed herein are not to be understood as being strictly limited to the exact numerical values recited. Instead, unless otherwise specified, each such dimension is intended to mean both the recited value and a functionally equivalent range surrounding that value. For example, a dimension disclosed as "40 mm" is intended to mean "about 40 mm."

[0085] Every document cited herein, if any, including any cross- referenced or related patent or application and any patent application or patent to which this application claims priority or benefit thereof, is hereby incorporated herein by reference in its entirety unless expressly excluded or otherwise limited. The citation of any document is not an admission that it is prior art with respect to any feature disclosed or claimed herein or that it alone, or in any combination with any other reference or references, teaches, suggests or discloses any such invention. Further, to the extent that any meaning or definition of a term in this document conflicts with any meaning or definition of the same term in a document incorporated by reference, the meaning or definition assigned to that term in this document shall govern.

[0086] While particular embodiments of the present disclosure have been illustrated and described, it would be obvious to those skilled in the art that various other changes and modifications can be made without departing from the spirit and scope of the disclosure. It is therefore intended to cover in the appended claims all such changes and modifications that are within the scope of this disclosure.

Claims

1. A stretched filament formed from a blend comprising:

at least one functionalized polymer, wherein the functionalized polymer is a propylene-based polymer having one or more functional groups grafted on the propylene-based polymer, wherein the one or more functional groups is selected from the group consisting of amine groups and imide groups, wherein the at least one functionalized polymer has a DSC melting point from 100 °C to 130 °C; and
a non-functionalized polyolefin;
wherein when the stretched filament is stretched to a stretch ratio of 5, the stretched filament has a tenacity greater than 0.90 cN/dtex.

2. The stretched filament of claim 1, wherein the non-functionalized polyolefin comprises an ethylene/alpha-olefin copolymer having a density (measured according to ASTM D792) of from 0.900 g/cc to 0.950 g/cc and a melt flow rate (MFR), I_2, measured according to ASTM D 1238 (190 °C and 2.16 kg), of from 0.1 g/10 min to 10 g/10 min.

3. The stretched filament of claim 1, wherein the non-functionalized polyolefin comprises an ethylene/alpha-olefin copolymer having a density (measured according to ASTM D792) of from 0.915 g/cc to 0.940 g/cc and a melt flow rate (MFR), I_2, measured according to ASTM D 1238 (190 °C and 2.16 kg), of from 0.7 g/10 min to 5 g/10 min.

4. The stretched filament of claims 2 or 3, wherein the ethylene/alpha-olefin copolymer has a melt flow ratio, I_{10}/I_2, of from 5 to 14, wherein I_{10} is measured according to ASTM D1238 (190 °C and 10kg).

5. The stretched filament of any preceding claim, wherein the non-functionalized polyolefin comprises a polypropylene homopolymer.

6. The stretched filament of claim 5, wherein the polypropylene homopolymer has a melt flow rate (MFR) of 0.5 g/10 min to 25 g/10 min.

7. The stretched filament of claim 5, wherein the polypropylene homopolymer has a MFR of 0.5 g/10 min to 10 g/10 min.

8. The stretched filament of claims 1-7, wherein the functionalized polymer has a graft level of from 0.1 wt.% to 3.0 wt.%.

9. The stretched filament of claims 1-8, wherein the propylene-based polymer is a propylene/ethylene copolymer or a propylene/alpha-olefin copolymer wherein the alpha-olefin is a C_4-C_{20} alpha-olefin.

10. The stretched filament of claim 1, wherein the at least one functionalized polymer has a melt flow rate (MFR), I_2, measured according to ASTM D 1238 (190 °C and 2.16 kg), of from 1 g/10 min to 20 g/10 min.

11. An artificial turf system comprising:

a primary backing;
a secondary backing; and
the stretched filament of claim 1.

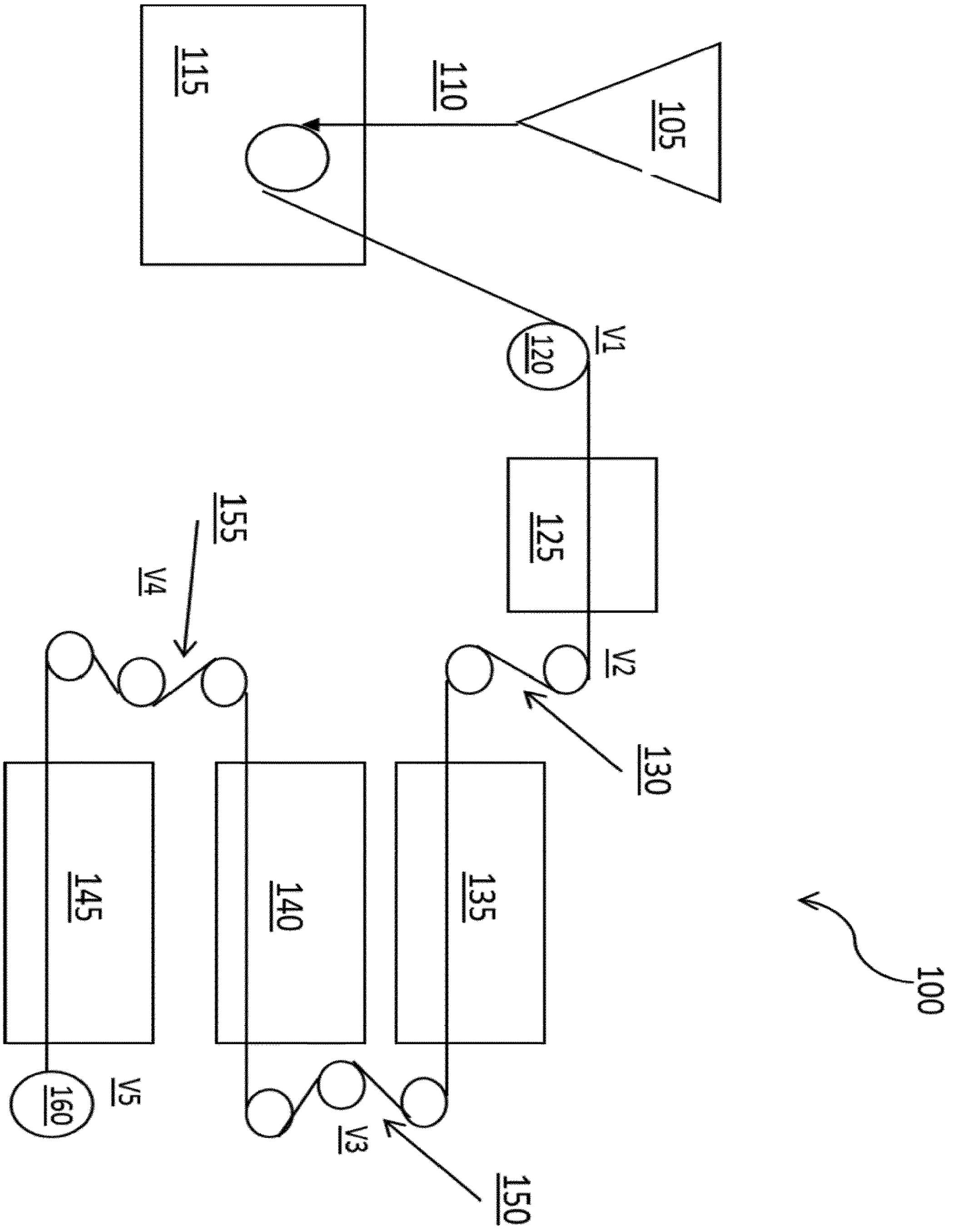


FIG. 1A

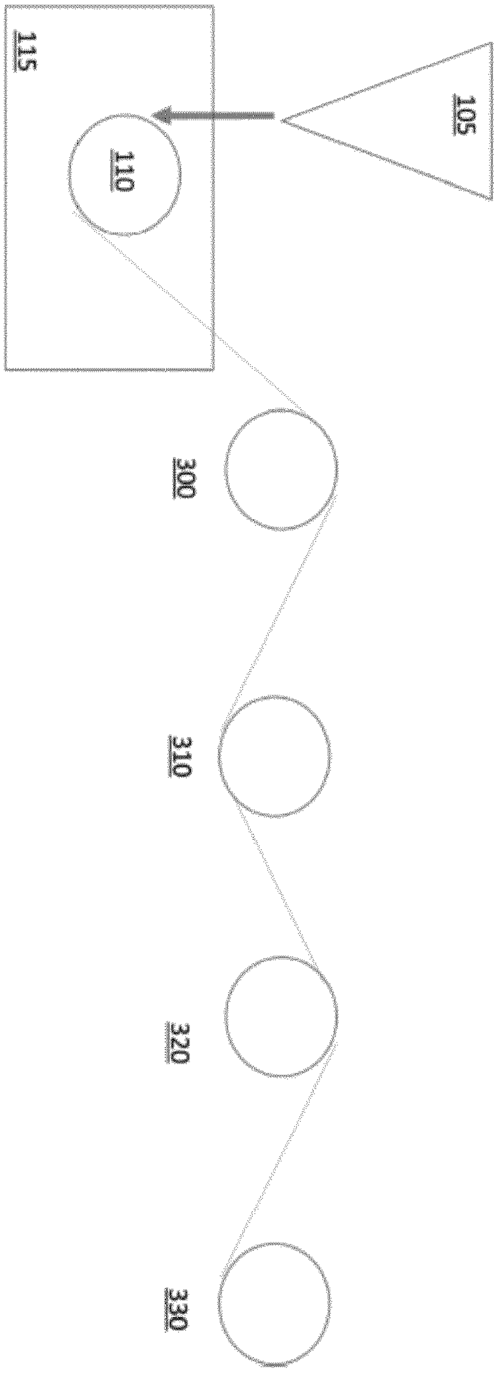


FIG. 1B

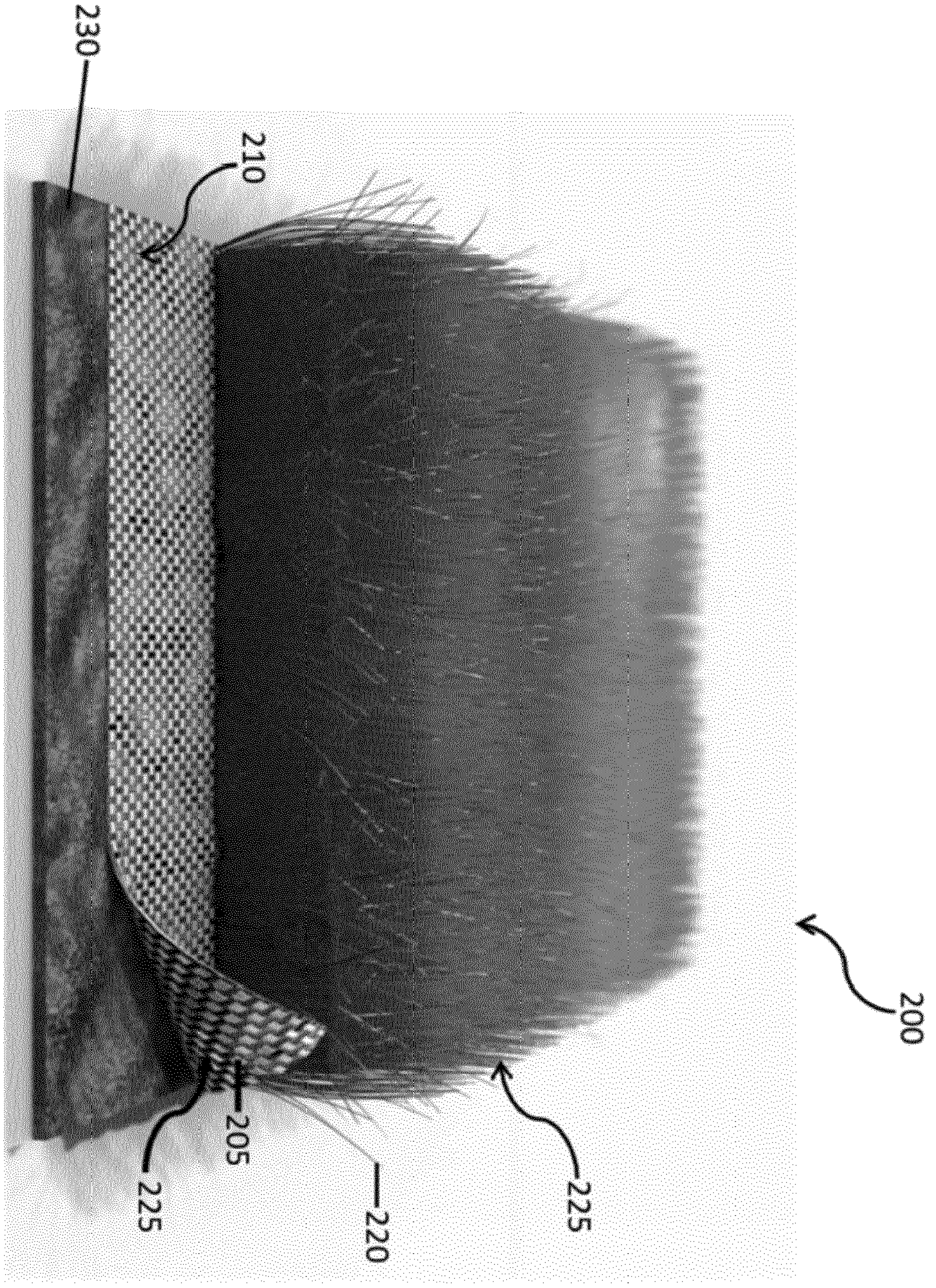


FIG. 2

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EUROPEAN SEARCH REPORT

Application Number
EP 16 38 2313

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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TECHNICAL FIELDS SEARCHED (IPC)

D01F
E01C

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	31 August 2016	Malik, Jan

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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D : document cited in the application
L : document cited for other reasons
& : member of the same patent family, corresponding document

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EPO FORM 1503 03.82 (P04C01)

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31-08-2016

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For more details about this annex : see Official Journal of the European Patent Office, No. 12/82

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