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(54) Title: ARTIFICIAL TURF FILAMENTS, AND ARTICLES MADE THEREFROM

(57) Abstract: An artificial turf filament comprising a polyolefin, a polyamide, a polyester, or a combination thereof, wherein the filament has a surface area, with at least a portion of the surface area being halogenated to form a halogenated surface
ARTIFICIAL TURF FILAMENTS,
AND ARTICLES MADE THEREFROM

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 turf fields are increasingly being used as an alternative to natural grass turf for use on sport athletic fields, landscaping, or golf applications. However, conventional artificial turf fields can have poor attachment of the synthetic grass blades to the base portion of an artificial turf field resulting in easy detachment of the grass blades. In addition, further improvements are desired of artificial turf fields to reduce the amount of heat absorbed, as well as, providing improved sports performance characteristics (e.g., faster ball roll). Water may be applied to the artificial turf field to achieve the desired turf performance characteristics, while also controlling heat; however, the water can easily run off the surface of the synthetic grass blades resulting in poor cooling of the yarns and/or failure to provide the desired sports performance characteristics. Further, while artificial turf fields have improved over the years to appear more like natural grass, synthetic grass blades still exhibit a smoother, glossy appearance when compared to natural grass, which is not aesthetically pleasing.

[0003] Accordingly, alternative artificial turf fields and artificial turf filaments/yarns having good adhesive, thermal and/or appearance properties are desired.

SUMMARY

[0004] Disclosed in embodiments herein is an artificial turf filament comprising a polyolefin, a polyamide, a polyester, or a combination thereof, wherein the filament has a surface area, with at least a portion of the surface area being halogenated to form a halogenated surface. Also disclosed herein are method of manufacturing such artificial turf filaments, artificial turf fields comprising such filaments, and methods of manufacturing the artificial turf fields.
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.

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

FIG. 1 pictorially depicts a cutaway view of an artificial turf field according to one or more embodiments shown and described herein.

FIGS. 2A & 2B pictorially depict an artificial turf filament according to one or more embodiments shown and described herein as compared to a comparative filament after peel adhesion testing.

FIGS. 3A & 3B pictorially depict the behavior of a water drop on the surface of an artificial turf filament according to one or more embodiments shown and described herein as compared to a water drop on the surface of a comparative filament.

FIG. 4 graphically depicts a water contact angle comparison of an artificial turf filament according to one or more embodiments shown and described herein and a comparative filament.

FIG. 5 graphically depicts a water contact angle comparison after weathering of an artificial turf filament according to one or more embodiments shown and described herein and a comparative filament.
FIGS. 6A & 6B pictorially depict scanning electron microscopy images of the surface of an artificial turf filament according to one or more embodiments shown and described herein as compared to the surface of a comparative filament.

FIGS. 7A & 7B graphically depict differential scanning calorimetry curves for an artificial turf filament according to one or more embodiments shown and described herein as compared to a comparative filament.

DETAILED DESCRIPTION

Reference will now be made in detail to embodiments of artificial turf filaments, artificial turf fields incorporating artificial turf filaments, and method of making artificial turf filaments and artificial turf fields, 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 stretched fibrous materials used to form synthetic grass blades or strands of an artificial turf field.

Artificial Turf Filaments

The artificial turf filaments described herein comprise a polyolefin, a polyamide, a polyester, or a combination thereof. Polyolefins include polymers derived from one or more simple olefin monomers, e.g., ethylene, propylene, 1-butene, 1-hexene, or 1-octene. The olefin monomers can be substituted or unsubstituted, and if substituted, the substituents can vary widely. Exemplary polyolefins can include polyethylene, polypropylene, polybutene, polyisoprene and their various interpolymers. As used herein, "interpolymer" refers to polymers prepared by the polymerization of at least two different types of monomers. The term "interpolymer" can include copolymers, which is used to refer to polymers prepared from two different types of monomers, and can also include polymers prepared from more than two different types of monomers. Other suitable polyolefins are described in U.S. Pat. No. 7,714,071, U.S. Pub. No. 2012/0129417, U.S. Pub. No. 2013/0023177, WO 2011/041698, which are incorporated herein by reference. It should be understood that blends of polyolefins may also be used herein.

In some embodiments, the artificial turf filament comprises a polyolefin, the polyolefin comprising polyethylene or polypropylene. In other embodiments, the artificial
turf filament comprises polyethylene. The polyethylene has, in polymerized form, a majority weight percent of ethylene, based on the total weight of the polyethylene. The polyethylene may be an interpolymer of ethylene and at least one ethylenically unsaturated comonomer, such as, for example, a C3-C20 a-olefin comonomer. In some embodiments, the comonomer is a C3-C8 a-olefin. In other embodiments, the C3-C8 a-olefin is selected from propylene, 1-butene, 1-hexene, or 1-octene. In further embodiments, the polyethylene is selected from ethylene/propylene copolymer, ethylene/hexene copolymer, and ethylene/octene copolymer. In even further embodiments, the polyethylene is an ethylene/octene copolymer.

The polyethylene has a density of 0.900 g/cc to 0.965 g/cc. All individual values and subranges of at least 0.900 g/cc to 0.965 g/cc are included and disclosed herein. For example, in some embodiments, the polyethylene has a density of 0.910 g/cc to about 0.950 g/cc, 0.910 to 0.940 g/cc, or 0.915 to 0.935 g/cc. The polyethylene has a melt index of 0.5 g/10 min to 10 g/10 min. All individual values and subranges of at least 0.5 g/10 min to 10 g/10 min are included and disclosed herein. For example, in some embodiments, the polyethylene has a melt index of 1 g/10 min to 8 g/10 min, 0.5 g/10 min to 5 g/10 min, 1 g/10 min to 5 g/10 min, or 1 g/10 min to 4 g/10 min, as measured in accordance with ASTM D1238 (190°C. and 2.16 kg).

The polyethylene can be produced with Ziegler-Natta catalysts, single-site catalysts, such as, vanadium catalysts or metallocene catalysts, or combinations thereof. In some embodiments, the polyethylene is produced with a Ziegler-Natta type catalyst. Nonlimiting examples of suitable Ziegler-Natta catalyzed polyethylene include polymers sold under the trade name DOWLEX™, available from The Dow Chemical Company, Midland, Mich., such as, for example, the DOWLEX™ 2025G resin, the DOWLEX™ SC 2108G resin, the DOWLEX™ 2036G resin, the DOWLEX™ 2045G resin, the DOWLEX™ SC 2107G resin, the DOWLEX™ 2607G resin, the DOWLEX™ 2055G resin, the DOWLEX™ 2247G resin, or the DOWLEX™ 2047G resin.

In other embodiments, the polyethylene is produced with a single-site catalyst, such as, a metallocene catalyst or a constrained geometry catalyst. A "metallocene catalyst" is a catalyst composition containing one or more substituted or unsubstituted cyclopentadienyl moiety in combination with a Group 4, 5, or 6 transition metal. Nonlimiting examples of suitable metallocene catalysts are disclosed in U.S. Pat.
No. 5,324,800, the entire content of which is incorporated herein by reference. A "constrained geometry catalyst" comprises a metal coordination complex comprising a metal of groups 3-10 or the Lanthanide series of the Periodic Table and a delocalized pi-bonded moiety substituted with a constrain-inducing moiety, said complex having a constrained geometry about the metal atom such that the angle at the metal between the centroid of the delocalized, substituted pi-bonded moiety and the center of at least one remaining substituent is less than such angle in a similar complex containing a similar pi-bonded moiety lacking in such constrain-inducing substituent, and provided further that for such complexes comprising more than one delocalized, substituted pi-bonded moiety, only one thereof for each metal atom of the complex is a cyclic, delocalized, substituted pi-bonded moiety. The constrained geometry catalyst may further comprise an activating co-catalyst. Nonlimiting examples of suitable constrained geometry catalysts are disclosed U.S. Pat. No. 5,132,380, the entire content of which is incorporated by reference herein.

[0020] The single-site polyethylene may be unimodal or multimodal (e.g., bimodal). A unimodal polyethylene polymer is prepared from one single-site catalyst under one set of polymerization conditions. Nonlimiting examples of suitable unimodal polyethylene polymers include those sold under the trade names EXACT™ and EXCEED™, available from the ExxonMobil Chemical Company, Houston, Texas; and ENGAGE™ and AFFINITY™, available from The Dow Chemical Company, Midland, Mich. A multimodal polyethylene polymer is prepared from one, two, or more different catalysts and/or under two or more different polymerization conditions. Each component may be prepared with a different catalyst and/or under different polymerization conditions. The prefix "multi" relates to the number of different polymer components present in the polymer. Nonlimiting examples of multimodal polyethylene polymers are set forth in U.S. Pat. No. 5,047,468, the entire content of which is incorporated by reference herein, and include those polymers sold under the trade name ELITE™, available from The Dow Chemical Company, Midland, Mich.

[0021] Polyamides may include, but are not limited to, polymers produced by a polycondensation reaction of a diamine and a dicarboxylic acid, or from self-condensation of a lactam. Aliphatic, semi-aromatic, or aromatic polyamides can be used herein. In some embodiments, aliphatic polyamides are used. As used herein, "aliphatic polyamides" includes polyamides having a structure exclusively composed of aliphatic monomers. As
used herein, "semi-aromatic polyamides" includes polyamides having a structure composed of aliphatic and aromatic monomers. As used herein, "aromatic polyamides" includes polyamides having a structure composed exclusively of aromatic monomers. Suitable dicarboxylic acids can include, but are not limited to, adipic acid, pimelic acid, suberic acid, sebacic acid, dodecanedioic acid, azelaic acid, 1,10-decanedicarboxylic acid, terephthalic acid, isophthalic acid and 2,6-naphthalenedicarboxylic acid. Suitable diamines can include, but are not limited to, hexamethylenediamine, octamethylenediamine, metaxylylenediamine, paraxylylenediamine, 1,3-bis(aminomethyl)cyclohexane, 1,4-bis(aminomethyl)cyclohexane, tetramethylenediamine, nonamethylenediamine, and 2-methyl-1,5-pentanediamine. It should be understood that blends of polyamides may also be used herein.

[0022] Exemplary polyamides can include polyhexamethylene adipamide, polyhexamethylene azelaamide, polyhexamethylene sebacamide, polyhexamethylene dodecanoamide, poly bis-(4-aminocyclohexyl)methane dodecanoamide, or the polyamides produced by ring opening of lactams; e.g., polycaprolactam, polylauryl lactam, or poly-11-aminoundecanoamide. In some embodiments, the polyamide is polyhexamethylene adipamide or polycaprolactam, or mixtures thereof.

[0023] Polyesters may include, but are not limited to, polymers obtained through polymerization of a dicarboxylic acid and a diol. Suitable dicarboxylic acids can include, but are not limited to, terephthalic acid, isophthalic acid, 2,6-naphthalenedicarboxylic acid; naphthalenedicarboxylic acids, 1,5-naphthalenedicarboxylic acid, 2,7-naphthalenedicarboxylic acid, 4,4'-biphenyldicarboxylic acid, 3,4'-biphenyldicarboxylic acid, and their ester-forming derivatives. Aliphatic dicarboxylic acid, such as, adipic acid or sebacic acid, may also be used. Suitable diols may include, but are not limited to, aliphatic diols, such as, ethylene glycol, 1,3-propylene glycol, 1,4-butanediol, 1,4-cyclohexanediol, 1,6-hexanediol, and their ester-forming derivatives.

[0024] Exemplary polyesters can include, but are not limited to, ethylene terephthalate resin, ethylene isophthalate, polyalkylene terephthalates, polyethylene terephthalate/isophthalate copolymer resin, polyethylene/1,4-cyclohexanediolylene terephthalate copolymer resin, polyethylene 2,6-naphthalenedicarboxylate resin, polyethylene 2,6-naphthalenedicarboxylate/terephthalate copolymer resin, polyethylene terephthalate/4,4'-biphenyldicarboxylate resin, poly-1,3-propylene terephthalate resin, polybutylene terephthalate resin, polybutylene 2,6-naphthalenedicarboxylate resin. In some embodiments,
the polyester is ethylene terephthalate resin, ethylene isophthalate, polyalkylene terephthalate resin, polyethylene/1,4-cyclohexanedicarboxylic acid terephthalate copolymer resin, or polyethylene terephthalate/isophthalate copolymer resin.

[0025] 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, anti-blocking agents, surfactants, extenders, acid scavengers, and metal deactivators. 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.

[0026] Nonlimiting examples of pigments include inorganic pigments that are suitably colored to provide an aesthetic appeal including various shades of green, white (TiO₂, rutile), iron oxide pigments, and any other color.

[0027] Examples of antioxidants include, but are not limited to, hindered phenols, such as tetrakis[methylene(3,5-di-tert-butyl-4-hydroxyhydrocinnamate)] methane; bis[(beta-(3,5-ditert-butyl-4-hydroxybenzyl)-methylcarboxyethyl)] sulphide, 4,4′-thiobis(2-methyl-6-tert-butylphenol), 4,4′-thiobis(2-tert-butyl-5-methylphenol), 2,2′-thiobis(4-methyl-6-tert-butylphenol), and thiodiethylene bis(3,5-di-tert-butyl-4-hydroxyhydrocinnamate; phosphites and phosphonites, such as, tris(2,4-di-tert-butylphenyl)phosphate and di-tert-butylphenylphosphonite; thio compounds, such as, dilaurylthiodipropionate, dimyristylthiodipropionate, and distearylthiodipropionate; various siloxanes; polymerized 2,2,4-trimethyl-1,2-dihydroquinoline, n,n′-bis(1,4-dimethylpentyl-p-phenylenediamine), alkylated diphenylamines, 4,4′-bis(alpha, alpha-dimethylbenzyl) diphenylamine, diphenyl-p-phenylenediamine, mixed di-aryl-p-phenylenediamines, and other hindered amine anti-degradants or stabilizers.

[0028] Examples of curing agents include, but are not limited to, dicumyl peroxide, bis(alpha-t-butyl peroxyisopropyl)benzene, isopropylcumyl t-butyl peroxide, t-butylcumylperoxide, di-t-butyl peroxide, 2,5-bis(t-butylperoxy)2,5-dimethylhexane, 2,5-bis(t-butylperoxy)2,5-dimethylhexyne-3,1,1-bis(t-butylperoxy)3,3,5-trimethylecyclohexane, isopropylcumyl cumylperoxide, di(isopropylcumyl) peroxide, or mixtures thereof. Various
other known curing co-agents, boosters, and retarders, can be used, such as triallyl isocyanurate, ethyoxylated bisphenol A dimethacrylate, α-methyl styrene dimer, and other co-agents described in U.S. Pat. Nos. 5,346,961 and 4,018,852.

[0029] Examples of processing aids include, but are not limited to, metal salts of carboxylic acids, such as, zinc stearate or calcium stearate; fatty acids, such as, stearic acid, oleic acid, or erucic acid; fatty amides, such as, stearamide, oleamide, erucamide, or η,η'-ethylenebisstearamide; polyethylene wax; oxidized polyethylene wax; polymers of ethylene oxide; copolymers of ethylene oxide and propylene oxide; vegetable waxes; petroleum waxes; non-ionic surfactants; and polysiloxanes.

[0030] Examples of UV stabilizers and UV absorbers include, but are not limited to, hindered amine light stabilizers, benzophenone, benzotriazole, hydroxyphenyl triazine, 2-(2'-hydroxyphenyl)benzotriazoles, the UVINUL® 3000 UV absorber, the TINUVIN™ P UV absorber, the IRGANOX™ 1098 antioxidant, the UVINUL® 3008 UV absorber, the TINUVIN™ 320 UV absorber, the IRGANOX™ 1010 antioxidant, the IRGANOX™ 1076 antioxidant, and the IRGAfos™ 168 antioxidant.

[0031] 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 stretched fibrous materials used to form synthetic grass blades or strands of an artificial turf field. The artificial turf filament may optionally undergo further post-extrusion processing (e.g., annealing, cutting, etc.).

[0032] In embodiments herein, the artificial turf filament has a surface area, with at least a portion of the surface area being halogenated to form a halogenated surface. Suitable halogens may include fluorine, chlorine, bromine, or iodine. In some embodiments, the halogen is fluorine, and at least a portion of the surface area is fluorinated to form a fluorinated surface. The surface area to be treated is exposed to a composition containing a suitable source of a reactive halogen, such as, for example, halogen-containing plasmas, halogen-containing gas mixtures, halogen dissolved in solvents, or UV-activated halogen gas mixtures. In some embodiments, the surface area is exposed to a gas mixture containing a halogen.
The amount of halogen needed to enhance properties of the artificial turf filament is relatively minor. In embodiments herein, the artificial turf filament is exposed to a composition containing a halogen at a concentration of at least 0.1 wt.%, at least 1 wt.%, at least 5 wt.%, or at least 10 wt.% of a halogen. All individual values and subranges of at least 0.1 wt.% are included and disclosed herein. For example, in some embodiments, the artificial turf filament is exposed to a composition containing a halogen at a concentration of 0.1 wt.% to 50 wt.%, 0.1 wt.% to 40 wt.%, 0.1 wt.% to 30 wt.%, 0.1 wt.% to 20 wt.%, 0.1 wt.% to 15 wt.%, or 0.1 wt.% to 10 wt.%. In other embodiments, the artificial turf filament is exposed to a pure or substantially pure halogen composition. The artificial turf filament may be exposed to a composition containing a halogen for a period of 0.1 seconds to 15 minutes, 0.5 seconds to 5 minutes, 0.5 second to 2 minutes, 0.5 second to 60 seconds, 0.5 second to 30 seconds, or 0.5 to 15 seconds. Of course, all individual values and subranges of 0.1 seconds to 15 minutes are included and disclosed herein.

The temperature of the composition containing a halogen and the artificial turf filament can be any temperature that is suitable for the process being used. In some embodiments, the temperature of the artificial turf filament and/or the composition containing a halogen may range from -50°C to 100°C, -30°C to 80°C, -15°C to 70°C, -5°C to 50°C, 5°C to 40°C, 10°C to 30°C, and 15°C to 25°C. The composition containing a halogen can be exposed to the artificial turf filament at pressures from 0.1 to 50 atmospheres (atms). All individual values and subranges from 0.1 to 50 atms are included and disclosed herein. For example, in some embodiments, the composition containing a halogen can be exposed to the artificial turf filament at pressures from 0.5 to 25 atms, from 0.75 to 10 atms, from 1.0 to 5.0 atms, or from 0.75 to 1.25 atms. Any combinations of the above halogens, amounts, times, and temperatures can be used, depending on the application, and values other than those explicitly given can be used, depending on the application, and are considered within the spirit and scope of the invention.

In some embodiments, the artificial turf filament is exposed to a composition containing fluorine at a concentration of at least 0.1 wt.%, at least 1 wt.%, at least 5 wt.%, or at least 10 wt.% of fluorine. All individual values and subranges of at least 0.1 wt.% are included and disclosed herein. For example, in some embodiments, the artificial turf filament is exposed to a composition containing fluorine at a concentration of 0.1 wt.% to 50 wt.%, 0.1 wt.% to 40 wt.%, 0.1 wt.% to 30 wt.%, 0.1 wt.% to 20 wt.%, 0.1 wt.% to 15 wt.%, or
0.1 wt.% to 10 wt.%. In other embodiments, the artificial turf filament is exposed to a pure or substantially pure fluorine composition. The artificial turf filament may be exposed to a composition containing fluorine for a period of 0.1 seconds to 15 minutes, 0.5 seconds to 5 minutes, 0.5 second to 2 minutes, 0.5 second to 60 seconds, 0.5 second to 30 seconds, or 0.5 to 15 seconds. Of course, all individual values and subranges of 0.1 seconds to 15 minutes are included and disclosed herein.

[0036] The composition containing fluorine can have any temperature that is suitable for the process being used. In some embodiments, the composition containing fluorine may have a temperature from -50°C to 100°C, -30°C to 80°C, -15°C to 70°C, -5°C to 50°C, 5°C to 40°C, 10°C to 30°C, and 15°C to 25°C. The composition containing fluorine can be exposed to the artificial turf filament at pressures from 0.1 to 50 atmospheres (atms). All individual values and subranges from 0.1 to 50 atms are included and disclosed herein. For example, in some embodiments, the composition containing fluorine can be exposed to the artificial turf filament at pressures from 0.5 to 25 atms, from 0.75 to 10 atms, from 1.0 to 5.0 atms, or from 0.75 to 1.25 atms.

[0037] In embodiments where the surface area is exposed to a gas mixture containing a halogen, or in some embodiments, fluorine, the halogen or fluorine may be employed as a mixture with other gases, such as, oxygen, nitrogen, carbon dioxide, noble gases, such as, helium or argon, hydrogen halides, such as, hydrogen chloride or hydrogen bromide, vapours, such as, water vapour and/or solvent vapours, such as, methylene chloride vapour. Exposure of at least a portion of the surface area of the artificial turf filament to a composition containing a halogen, or in some embodiments, fluorine, may be accomplished via batch or continuous operations.

[0038] It has been found that halogenated surfaces, including fluorinated surfaces, modify the artificial turf filament to enhance the filament properties. For example, the artificial turf filaments described herein have increased adhesion to a polyurethane substrate, improved hydrophilicity, an observed fiber elongation at break that is less than 10% different, or an observed fiber force at break that is less than 5% different, when compared to a non-halogenated artificial turf filament. In addition, it has been found that the artificial turf filaments described herein have improved hydrophilicity as evidenced by a water contact angle of less than 80 degrees. Also, it has been found that the artificial turf filaments
described herein have no significant structural modifications due to the halogenation process, or in some embodiments, the fluorination process.

[0039] It has been found that artificial turf filaments produced from polyolefins possess little to no polarity, while polyurethane substrates used in artificial turf fields are polar in nature. This can result in poor adhesion between the filament and the polyurethane substrate, allowing for easy detachment of the filament. Without being bound by theory, it is believed that by halogenating at least a portion of the surface of the artificial turf filament, the artificial turf filaments described herein are polarized such that the filaments will have improved adhesion to the polyurethane substrate.

[0040] In addition, it has been found that artificial turf filaments having little to no polarity can have a low surface tension such that when water is sprayed onto the filament, the water can easily run off the surface of the filament instead of forming a film or coat layer on the filament surface. Without being bound by theory, it is believed that by halogenating at least a portion of the surface of the artificial turf filament, the artificial turf filaments described herein have improved hydrophilicity, as evidenced by a water contact angle of less than 80 degrees, which can allow the filaments to better withstand thermal stresses and/or provide improved sports performance characteristics.

[0041] Further, it has been found that while artificial turf fields have improved over the years to appear more like natural grass, the artificial turf filaments may exhibit a smoother, glossy appearance when compared to natural grass. Without being bound by theory, it is believed that by halogenating at least a portion of the surface of the artificial turf filament, the artificial turf filaments described herein have an improved appearance due to an increase in the surface roughness of the filament that imparts a different light scattering pattern giving the artificial turf filaments a more matte appearance.

Artificial Turf Fields

[0042] One or more embodiments of the artificial turf filaments described herein, may be used to form an artificial turf field. Referring to FIG. 1, depicted is a cutaway view of an artificial turf field 100 according to one or more embodiments shown and/or described herein. The artificial turf field 100 comprises a primary backing 105 having a top side 110 and a bottom side 115; and at least one artificial turf filament 120 as previously described herein. The at least one artificial turf filament 120 is affixed to the primary backing 105 such that the
at least one artificial turf filament 120 provides a tufted face 125 extending outwardly from the top side 110 of the primary backing 105. 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 125 extends from the top side 110 of the primary backing 105, 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.

[0043] The primary backing 105 can include, but is not limited to, woven, knitted, or non-woven 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 100 may further comprise a secondary backing 130 bonded to at least a portion of the bottom side 115 of the primary backing 105 such that the at least one artificial turf filament 120 is affixed in place to the bottom side 115 of the primary backing 105. The secondary backing 130 may comprise polyurethane (including, for example, polyurethane supplied under the name ENFORCER™ or ENHANCER™ available from The Dow Chemical Company) or latex-based materials, such as, styrene-butadiene latex, or acrylates.

[0044] The primary backing 105 and/or secondary backing 130 may have apertures through which moisture can pass. The apertures may be generally annular in configuration and are spread throughout the primary backing 105 and/or secondary backing 130. 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 100.

[0045] The artificial turf field 100 may be manufactured by providing at least one artificial turf filament 120 as described herein and affixing the at least one artificial turf filament 120 to a primary backing 105 such that that at least one artificial turf filament 120 provides a tufted face 125 extending outwardly from a top side 110 of the primary backing 105. The artificial turf field 100 may further be manufactured by bonding a secondary backing 130 to at least a portion of the bottom side 115 of the primary backing 105 such that the at least one artificial turf filament 120 is affixed in place to the bottom side 115 of the primary backing 105.
In some embodiments, the halogenated or fluorinated surface of the at least one artificial turf filament 120 is formed prior to affixing the at least one artificial turf filament 120 to the primary backing 105. In other embodiments, the halogenated or fluorinated surface of the at least one artificial turf filament 120 is formed subsequent to affixing the at least one artificial turf filament 120 to the primary backing 105.

The artificial turf field 100 may optionally comprise a shock absorption layer underneath the secondary backing of the artificial turf field. The shock absorption layer 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, an elastomer foam of polyvinyl chloride, polyethylene, polyurethane, and/or polypropylene. Non-limiting examples of a shock absorption layer are the ENFORCER™ Sport Polyurethane Systems, and the ENHANCER™ Sport Polyurethane Systems (available from The Dow Chemical Company).

The artificial turf field 100 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).

The artificial turf field 100 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, such as, for example, the EXCELDRAIN™ Sheet 100 drainage system, the EXCELDRAIN™ Sheet 200 drainage system, and the EXCELDRAIN™ EX-T STRIP drainage system (available from American Wick Drain Corp., Monroe, N.C.).

The embodiments described herein may be further illustrated by the following non-limiting examples.
EXAMPLES

Inventive Filaments

[0051] A blend was prepared using 94 wt.% of an ethylene-octene interpolymer that was prepared via a solution polymerization process in a dual reactor configuration connected in series, having a melt index of approximately 3.5 g/10 minutes, and a density of approximately 0.920 g/cc, 5 wt.% of a commercially available color pigment (masterbatch 90-125335 supplied by BASF SE, Germany), and 1 wt.% of a commercially available fluoroelastomer processing aid (VIBATAN™ LLDPE Process Aid 433B, supplied by Viba S.p.A., Italy).

[0052] Artificial turf filaments were extruded on a Barmag/Oerlikon monofilament extrusion line (Chemnitz, DE) using the blend described above. The Barmag/Oerlikon monofilament extrusion line includes a 40 mm extruder, a spinneret with 48 holes, a water bath, one stretching oven (hot air), and three annealing ovens (air). The water bath was set at 35°C. The air gap between the spinneret and the water bath was set at 40 mm for all trials. The temperature of the stretching oven was set at 97°C. Annealing ratios were set at, respectively, 0.72, 0.92 and 1.02 and the temperature of the three annealing ovens were set at, respectively, 118°C, 118°C and 115°C.

[0053] The final process settings were as follows:

<table>
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<tr>
<th>Filament Titer (dtx)</th>
<th>Stretch Ratio</th>
<th>Final Line Speed (m/min)</th>
<th>Extruder Output (kg/h)</th>
<th>Pressure before the spinneret (bar)</th>
<th>Melt Temperature (°C)</th>
</tr>
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<tbody>
<tr>
<td>2110</td>
<td>5.32</td>
<td>160</td>
<td>95.4</td>
<td>103.2</td>
<td>226.1</td>
</tr>
</tbody>
</table>

[0054] 50 m of yarn were sent to FluorTechnik GmbH for fluorination of at least part of a surface area of the yarn in a batch reactor. Fluorination took place at room temperature, for about 15 seconds, using a gas mixture containing about 10 wt.% elemental fluorine mixed with inert gas.
Comparative Filaments

[0055] A blend was prepared using 94 wt.% of an ethylene-octene interpolymer that was prepared via a solution polymerization process in a dual reactor configuration connected in series, having a melt index of approximately 3.5 g/10 minutes, and a density of approximately 0.920 g/cc, 5 wt.% of a commercially available color pigment (masterbatch 90-125335 supplied by BASF SE, Germany), and 1 wt.% of a commercially available fluoroelastomer processing aid (VIBATAN™ LLDPE Process Aid 433B, supplied by Viba S.p.A., Italy).

[0056] Artificial turf filaments were extruded on a Barmag/Oerlikon monofilament extrusion line (Chemnitz, DE) using the blend described above. The Barmag/Oerlikon monofilament extrusion line includes a 40 mm extruder, a spinneret with 48 holes, a water bath, one stretching oven (hot air), and three annealing ovens (air). The water bath was set at 35°C. The air gap between the spinneret and the water bath was set at 40 mm for all trials. The temperature of the stretching oven was set at 97°C. Annealing ratios were set at, respectively, 0.72, 0.92 and 1.02 and the temperature of the three annealing ovens at respectively 118°C, 118°C and 115°C.

[0057] The final process settings were as follows:

<table>
<thead>
<tr>
<th>Filament Titer (dtex)</th>
<th>Stretch Ratio</th>
<th>Final Line Speed (m/min)</th>
<th>Extruder Output (kg/h)</th>
<th>Pressure before spinneret (bar)</th>
<th>Melt Temperature (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2110</td>
<td>5.32</td>
<td>160</td>
<td>95.4</td>
<td>103.2</td>
<td>226.1</td>
</tr>
</tbody>
</table>

[0058] Inventive filaments were then analyzed and compared to comparative filaments for adhesion peel strength, hydrophilicity, tensile properties, surface roughness, and differential scanning calorimetry. In addition, the inventive filaments were also analyzed and compared to the comparative filaments after exposure to accelerated weathering conditions for 1300 hours in the Xenon chamber of a weathering machine Q-sun XE-2 Xenon Test Chamber (Q-lab). The exposure time of 1300 hours was set to mimic 1 year of sun exposure in a climate similar to Florida.
Adhesive Peel Strength Testing

[0059] A CRE tensile testing machine (Instron) was used to measure the peel force of inventive and comparative filaments from a polyurethane substrate. To prepare the specimens, a polyurethane precursor composition was poured onto a 9" x 12" sheet. Inventive and comparative filaments were each applied to the poured polyurethane precursor composition, and then heated for 15 minutes at 120°C. The specimens were subsequently allowed to cure for at least three days. Each specimen was sized to have a length x width x height of about 6" (150 mm) x 0.5" (12.7 mm) x 1/64" (0.20 mm).

[0060] At a first end of the specimen, one inch of the filament was manually separated from the polyurethane substrate. The starting gap between the grips was set to 1" (25.4 mm) and the filament was placed in the movable grip while the polyurethane substrate was placed in the stationary grip. The filaments were peeled from the polyurethane substrate at a rate of 12 in/min (300 mm/min) until either the filament broke or until only one inch of filament/polyurethane substrate was left at the second end of the specimen. A trace is generated consisting of a series of peaks representing the force to peel the filament from the polyurethane substrate. To calculate the average peel force for a specimen, the initial peak force was ignored (which represents approximately 0.5 inches of specimen separation), and the average of all peaks between the initial peak force and the stopping point was determined. At least five specimens of the inventive filaments were measured and at least five specimens of the comparative filaments were measured. The average of the five measurements for the inventive and for the comparative filaments was calculated.

[0061] Referring to FIG. 2A, depicted is an inventive filament after peeling. The filament was not easily peeled from the polyurethane substrate, and is shown with much of the inventive filament still adhered to the polyurethane substrate due to the filament breaking while it was peeled. Referring to FIG. 2B, the comparative filament was easily peeled from the polyurethane substrate, and the comparative filament is shown completely separated from the polyurethane substrate.

[0062] The force to peel the inventive and comparative filaments from the polyurethane substrate was measured at room temperature and after aging at 70°C in H₂O for 4 hours and 30 minutes.
<table>
<thead>
<tr>
<th></th>
<th>Average Peel Strength at Room Temp. (lbf)</th>
<th>Average Peel Strength after Aging (lbf)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inventive Filaments</td>
<td>0.24 +/- 0.06</td>
<td>0.29 +/- 0.04</td>
</tr>
<tr>
<td>Comparative Filaments</td>
<td>0.04 +/- 0.03</td>
<td>0.05 +/- 0.02</td>
</tr>
</tbody>
</table>

[0063] The results show that a higher force is required to peel the inventive filaments from the polyurethane substrate as compared to the comparative filaments, and therefore, increased adhesion is achieved between the inventive filament and the polyurethane substrate as compared to the comparative filaments.

Hydrophilicity

[0064] The hydrophilic properties of the inventive and comparative filaments were analyzed with respect to their respective water contact angles with tap water at room temperature, using standard contact angle measuring equipment, to compare the polarity of the filaments. The water droplet on the comparative filament shown in FIG. 3B has a more circular shape, and therefore, a higher water contact angle, than the water droplet on the inventive filament shown in FIG. 3A. Further, as shown in FIG. 4, the measured water contact angle value is lower for the inventive filament as compared to the comparative filament, indicating that the inventive filament surface has improved hydrophilicity (i.e., a more hydrophilic and polar surface), as compared to the comparative filament.

[0065] The hydrophilic properties of the inventive and comparative filaments were also analyzed with respect to their respective water contact angles using tap water at room temperature after weathering (as described above) of the filaments, using contact angle measuring equipment. As shown in FIG. 5, the measured water contact angle value is lower for the inventive filament as compared to the comparative filament, even after weathering, indicating that the inventive filament surface has improved hydrophilicity (i.e., a more hydrophilic and polar surface), as compared to the comparative filament.

Tensile Test

[0066] Tensile testing was performed on the inventive and comparative filaments to compare the fiber elongation at break and fiber force at break.
Fiber Elongation At Break & Fiber Force At Break

[0067] Inventive and comparative filaments were measured for elongation % (i.e., the distance in percent that the filament sample will stretch from its original size to the point at which it breaks) and fiber force at break (i.e., the force required to break the filament sample in a linear direction) at break using an Instron tensile testing machine. The tests were performed at room temperature. Eight inventive filament samples having a fiber titer of 2050 dTex and a length of 100 mm were pulled at a test speed of 100 mm/min until break, at which point the elongation percent and force is recorded. Eight comparative filament samples having a fiber titer of 2030 dTex and a length of 100 mm were pulled at a test speed of 100 mm/min until break, at which point the elongation percent and force is recorded.

[0068] The fiber elongation at break % was calculated to be the average of the eight elongation percent measurements for the inventive filaments and the average of the eight elongation percent measurements for the comparative filaments. The fiber force at break was calculated to be the average of the eight peak force measurements for the inventive filaments divided by its fiber titer, and the average of the eight peak force measurements for the comparative filaments divided by its fiber titer.

<table>
<thead>
<tr>
<th></th>
<th>Fiber Elongation at Break (%)</th>
<th>Fiber Force at Break (cN/dTex)</th>
<th>Fiber Titer (dTex)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inventive Filaments</td>
<td>67</td>
<td>0.889</td>
<td>2050</td>
</tr>
<tr>
<td>Comparative Filaments</td>
<td>72</td>
<td>0.883</td>
<td>2030</td>
</tr>
</tbody>
</table>

[0069] The results show that the tensile properties of the inventive filaments are virtually unaffected by fluorination.

Surface Roughness

[0070] Scanning electron microscope analysis was performed on the inventive and comparative filaments to view and compare the surface roughness of the filaments. The samples of the inventive and comparative filaments were mounted on a sample holder using double-sided adhesive carbon discs, dried, and sputtered with a Cr coating using a Cressington 208HR high-resolution sputter-coater. The thickness of the Cr coating was set to 5.0 nm at a current of 80 mA. The samples were studied with a Philips XL30 FEG-SEM scanning electron microscope operating at an accelerating voltage of 20 kV.
FIG. 6A shows the surface of the comparative filament at 1,000X magnification (left photo) and at a 5,000X magnification (right photo). FIG. 6B shows the surface of the inventive filament at 1,000X magnification (left photo) and at 5,000X magnification (right photo). A visual comparison of the images shows that the surface of the inventive filament is rougher than the surface of the comparative filament.

**Differential Scanning Calorimetry (DSC)**

DSC was performed on the inventive and comparative filaments. The samples of each of the inventive and comparative filaments were heated to 50°C, cooled at 10°C/min, and the heat flow was recorded, as shown in FIG. 7A, by scanning from -40°C to 150°C at 10°C/min using DSC822e Differential Scanning Calorimeter (Mettler Toledo). The DSC cooling curve, as shown in FIG. 7B, was also recorded by scanning from 180°C to -40°C at 10°C/min. Referring to FIGS. 7A & 7B, the curves show that no structural modification occurred to the inventive filament due to the fluorination process.

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."

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 invention 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.

While particular embodiments of the present invention 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 invention. It is
therefore intended to cover in the appended claims all such changes and modifications that are within the scope of this invention. For example, use of the filaments herein in artificial turf fields for non-contact sports or in certain types of carpets.
CLAIMS:

1. An artificial turf filament comprising a polyolefin, a polyamide, a polyester, or a combination thereof, wherein the filament has a surface area, with at least a portion of the surface area being halogenated to form a halogenated surface.

2. The artificial turf filament of claim 1, wherein the at least a portion of the surface area is fluorinated to form a fluorinated surface.

3. The artificial turf filament of claim 1, wherein the filament comprises a polyolefin and the polyolefin comprises at least one of polyethylene or polypropylene.

4. The artificial turf filament of claim 1, wherein the filament comprises polyethylene and the polyethylene has a density of 0.910-0.940 g/cm³ and a melt index of 0.5-5 g/10 min.

5. The artificial turf filament of claim 1, wherein the halogenated surface modifies the filament to provide at least one of the following properties:
   increased adhesion to a polyurethane substrate,
   improved hydrophilicity,
   an observed fiber elongation at break that is less than 10% different, or
   an observed fiber force at break that is less than 5% different,
when compared to a non-halogenated filament.

6. The artificial turf filament of claim 1, wherein the artificial turf filament has improved hydrophilicity as measured by a water contact angle of less than 80 degrees.

7. A method of manufacturing the artificial turf filament of claim 1, the method comprising exposing the at least a portion of the surface area of the filament to a composition containing at least 5 wt.% of a halogen to form the halogenated surface.

8. The method of claim 7, wherein the halogen is fluorine.

9. An artificial turf field comprising:
   a primary backing having a top side and a bottom side; and
   at least one artificial turf filament according to claim 1;
wherein the at least one artificial turf filament is affixed to the primary backing such that the at least one artificial turf filament provides a tufted face extending outwardly from the top side of the primary backing.

10. The artificial turf field of claim 9, wherein the artificial turf field further comprises a secondary backing bonded to at least a portion of the bottom side of the primary backing such that the at least one artificial turf filament is affixed in place to the bottom side of the primary backing.

11. The artificial turf field of claim 9, wherein the secondary backing comprises polyurethane or styrene-butadiene latex.

12. A method of manufacturing artificial turf field, the method comprising: providing at least one artificial turf filament according to claim 1; and affixing the at least one artificial turf filament to a primary backing such that that at least one artificial turf filament provides a tufted face extending outwardly from a top side of the primary backing.

13. The method of claim 12, wherein the method further comprises bonding a secondary backing to at least a portion of the bottom side of the primary backing such that the at least one artificial turf filament is affixed in place to the bottom side of the primary backing.

14. The method of claim 13, wherein the secondary backing comprises polyurethane or styrene-butadiene latex.

15. The method of claim 12, wherein the halogenated or fluorinated surface of the at least one artificial turf filament is formed prior to affixing the at least one artificial turf filament to the primary backing.
**INTERNATIONAL SEARCH REPORT**

**A. CLASSIFICATION OF SUBJECT MATTER**

INV. D06M11/09

ADD.

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

D06M E01C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

EPO-Internal, WPI Data

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

<table>
<thead>
<tr>
<th>Category</th>
<th>Citation of document, with indication, where appropriate, of the relevant passages</th>
<th>Relevant to claim No.</th>
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<td>KARITONOV ET AL: &quot;Direct fluorination of polymers- From fundamental research to industrial applications&quot;. PROGRESS IN ORGANIC COATINGS, ELSEVIER BV, NL. vol. 61, no. 2-4. 26 November 2007 (2007-11-26), pages 192-204, XP022453203. ISSN: 0300-9440. DOI: 10.1016/J.P0RGCOAT.2007.09.027. abstract page 202, column 2, line 27 - line 57 ----. / -.</td>
<td>1-8</td>
</tr>
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</table>

Further documents are listed in the continuation of Box C.

See patent family annex.

* Special categories of cited documents:
  - "A" document defining the general state of the art which is not considered to be of particular relevance
  - "E" earlier application or patent but published on or after the international filing date
  - "L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
  - "O" document referring to an oral disclosure, use, exhibition or other means
  - "P" document published prior to the international filing date but later than the priority date claimed

* "T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

* "X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

* "Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

* "A" document member of the same patent family

Date of the actual completion of the international search: 23 April 2015

Date of mailing of the international search report: 04/05/2015

Name and mailing address of the ISA/ European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016

Authorized officer: Fiocco, Marco
### DOCUMENTS CONSIDERED TO BE RELEVANT

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<td>Kharitonov A P E D - O'Hagan: “Practical applications of the direct fluorination of polymers”, JOURNAL OF FLUORINE CHEMISTRY, ELSEVIER, NL, vol. 103, no. 2, 1 April 2000 (2000-04-01), pages 123-127, XP004199215, ISSN: 0022-1139, DOI: 10.1016/S0022-1139(99)0Q312-7 abstract section 4.</td>
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<td>J P H01 104881 A (TOSOH CORP) 21 April 1989 (1989-04-21) abstract examples table 1</td>
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<td>GB 1 395 949 A (AI R PROD &amp; CHEM) 29 May 1975 (1975-05-29) page 1, line 43 - 1 line 87 page 2, line 47 - 1 line 55</td>
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<td>EP 0 259 940 A2 (NIJVERDAL TEN CATE TEXTIEL [NL]) 16 March 1988 (1988-03-16) example 4 claims 6,7,19</td>
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