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(54) ARTIFICAL TURF WITH ANTI-SLIP AGENT RESERVOIR

(57) An artificial turf fiber comprising a polymer material and an anti-slip agent disposed within the polymer, characterized in that the anti-slip agent has an effective rate of migration in the polymer material and is provided in the polymer material in an effective amount to provide effective reduction of the fiber friction coefficient on the surface of the fiber for at least one year, preferably for at least 2 years, more preferably for at least 5 years, and most preferably for at least 10 years.

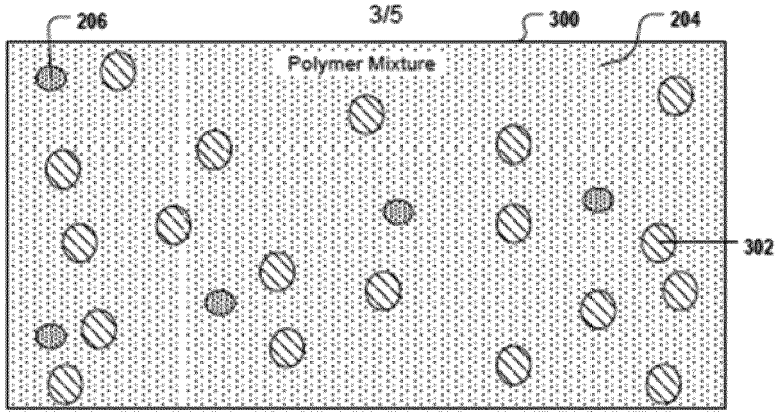

Fig. 3

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Description

Field of the invention

[0001] The invention relates generally to an artificial turf fiber and more particularly to an artificial turf fiber with an anti-slip agent reservoir, to an artificial turf using said artificial turf fiber and a method of making said artificial turf fiber.

Background

[0002] Artificial turf use for the surface of sport fields such as hockey, football, rugby etc. is increasing rather rapidly due to the convenience and economic efficiency of maintenance compared to natural turf. Existing artificial turfs used in such sport fields, especially hockey fields, require frequent watering to keep the surface of the turf adequately cool and smooth according to established standards promulgated by the governing bodies of these sports. Furthermore, the purpose of watering is to provide surface conditions that enable and maintain special playing characteristics. However, frequent watering is expensive and leads to water waste. Hence, there is a need of more advanced artificial turf which can overcome these drawbacks of heretofore known turfs.

[0003] Lubricants in the artificial turf industry have been used extensively, but primarily during the processing steps for making the artificial turf fibers or in the backing and infill materials of the artificial turf. Also, the use of reflective pigments for keeping artificial turfs cool has been reported in the literature. *See,* for example, US20170233956A1, and EP3936665A1 describing artificial turf infill compositions using lubricants and reflective pigments.

[0004] Various attempts have been made to produce artificial turf that looks natural and at the same time does not change its performance characteristics in different weather conditions. For example, US20220025587A1 describes an artificial turf which is said to have an improved, natural grass look and feel. The '587 patent application describes making a turf fiber having a composite structure of a core made of a first polymer and a shell made of a second polymer. The shell is said to be made of an acrylic polymer. The '587 patent application describes the use of stearic acid as an emulsifying agent used in the processing of the first polymer for the core of the turf fiber.

[0005] US9309630B2 describes an artificial turf for sports which allegedly changes little with varying moisture and temperature changes during play. The '630 patent employs a scrimless sheet of non-woven fibers which are held together by being entangled to one another. It is described that the free ends of some fibers as well as loops of some of the fibers may extend above the sheet.

[0006] US8691906B2 describes a process for producing at least one monofilament from a thermoplastic polymer material comprising at least one polyester material and also nanoparticles and optionally further additives including lubricants. The process comprises adding the components to an extruder as partial or complete mixtures or separately and the thermoplastic polymer material being initially strand extruded cooled and stretched and finally heat-conditioned at a temperature in the range from 40 to 120° C. for 0.01 to 10 min. The '906 patent describes that nanoparticles can be coupled with UV stabilizers and lubricants, when they are highly branched polyesters and/or polycarbonates

[0007] Despite the above rather limited attempts to produce artificial turf that can perform equally well in hot or wet weather and maintain its characteristics over a long period of time, to date there is no practical solution that can significantly reduce the need for watering the artificial turfs, especially in hot weather for field surfaces used in sports like hockey.

Summary of the Invention

[0008] The present invention overcomes the aforementioned limitations of existing artificial turfs.

[0009] An objective of the present invention is to provide an artificial turf fiber and an artificial turf using these fibers that is particularly suitable for the playing surface of sports like hockey and reduces significantly the need for frequent watering of the artificial turf.

[0010] Another objective of the present invention is the provision of an artificial turf having a surface that stays smooth and maintains its characteristics for the entire useful life of the artificial turf.

[0011] Another objective of the present invention is to provide an artificial turf that stays cooler at hot weather conditions.

[0012] Another objective of the present invention is to provide an artificial turf with enhanced tribological properties. The fiber surface of the present invention exhibits similar tribological and/or mechanical properties whether or not it is wet or dry. In sports like hockey the turf feels like a moist/irrigated artificial turf to the players even when this turf is not irrigated at all, thus saving water.

[0013] Another objective of the present invention is to provide an artificial turf that predominantly remains its performance characteristics regardless of whether it is irrigated/wet (e.g, after a rain shower) or dry, especially in very hot, sunny weather.

[0014] The solution provided by the present invention to the aforementioned objectives is an artificial turf comprising a polymer material and an anti-slip agent incorporated within the polymer, characterized in that the anti-slip agent has

an effective rate of migration in the polymer and is provided in an amount sufficient to last providing effective reduction of the fiber friction coefficient on the surface of the fiber for at a least one year, preferably for at least 2 years, more preferably for at least 5 years and most preferably for at least 10 years. Thus, the artificial turf is installed in the field with a reservoir of anti-slip agent to last reducing the friction coefficient of the fibers practically for the entire useful life of the artificial turf.

[0015] The anti-slip agent is incorporated into the polymer fiber and migrates to the surface driven by its diffusion coefficient to maintain an equal distribution of the anti-slip agent concentration within the volume. At the surface of the polymer fiber it modifies the surface chemistry, i.e., the friction coefficient and hence reduces the tribological interaction, thus providing protection of the fiber from friction, wear and abrasion.

[0016] An effective rate of migration means a rate that allows the anti-slip agent to last providing effective reduction of the fiber friction coefficient for the specified time.

[0017] An effective reduction of the fiber friction coefficient means to have an adequate amount of the anti-slip agent on the surface of the fiber to reduce the coefficient of friction of the fiber by at least weight 5%, preferably by at least 10 weight %, more preferably by at least 15% but no more than 25%.

[0018] The polymer material impacts the potential of the turf to store the anti-slip agent by deceleration of the migration speed of the anti-slip agent. It is selected from the group consisting of polyolefin homopolymers, polyolefin random copolymers, preferably polyethylene homopolymer fiber, polyethylene alloy fiber, polyethylene copolymer fiber, and polyethylene impact copolymer fiber. In an embodiment the fiber comprises LDPE, LLDPE, and/or HDPE and mixtures thereof. The LDPE may have a density from 0.905 g/cm^3 to 0.920 g/ cm^3, the LLDPE may have a density from 0.914 g/cm^3 to 0.928 g/cm^3, and the HDPE may have a density from 0.92 to 0.98 g/cm^3.

[0019] In an embodiment, the polymer material for the fiber is a mixture of low-density polyethylene (LDPE) and linear low-density polyethylene (LLDPE).

[0020] In an embodiment, the polymer material for the fiber is high density polyethylene (HDPE).

[0021] In another embodiment, the polymer material for the fiber is a mixture of LDPE and HDPE wherein the LLDPE is preferably from 10 to 70 wt% of the polymer material, more preferably from 15 to 50% wt%, and more preferably from 25 to 45 % of the total amount of LDPE and HDPE.

[0022] In another embodiment, the polymer material for the fiber is a mixture of LDPE and LLDPE wherein the LLDPE is preferably from 10 to 70 wt% of the polymer material, more preferably from 15 to 50% wt%, and more preferably from 25 to 45 % of the total amount of LDPE and LLDPE.

[0023] In another embodiment, the LLDPE may be a random copolymer of polyethylene with at least one of butene, hexene, and octene.

[0024] In a preferred embodiment, the polymer material for the fiber is a mixture of LLDPE and HDPE, with the LLDPE being hexene or octene comonomer based and having a density from 0.916 and 0.920 g/cm^3, while the HDPE has a density of 0.952 to 0.957 g/cm^3 and is in an amount of from 5-18 wt% of the holistic polymer mixture, and more preferably about 15 wt%.

[0025] Suitable anti-slip agents are fatty acid amides, and stearates i.e., salts and esters of stearic acid generally called stearates or an organo silicone product like a siloxane as e.g. of the type of polydimethylsiloxane.

[0026] Preferred fatty acid amides as anti-slip agents are the erucic acid amide (hereinafter EAA, also known as erucamide) lauramide, stearamide, oleamide, elaidamide, linoleamide, behenamide, palmitamide, N, N-ethylene-bis-oleamide, decanamide, and the like and mixtures thereof, and more preferred are the EEA, oleamide, linoleamide, and elaidamide.

[0027] Suitable stearic acid esters and salts include, for example, stearic acid methyl ester, stearic acid ethyl ester, and stearic acid N-hydroxysuccinimide ester ($C_{22}H_{39}NO_4$), sodium stearate, potassium stearate, and calcium stearate.

[0028] The anti-slip agent is used in an amount of from 0.05 to 1.0 wt%, preferably in an amount of from 0.1 to 0.7 wt%, more preferably from 0.2 to 0.6 wt% based on the total weight of the artificial turf fiber.

[0029] Preferably, the fiber also includes a reflective agent such as reflective particles, and/or reflective pigments for preventing overheating of the fiber and thus further reducing the need for watering the turf in hot weather conditions. These reflective particles and pigments have the advantage of reducing the heat on the artificial turf field, thereby further reducing the need for watering of the artificial turf. Suitable reflective agents include titanium dioxide, zinc sulfide (ZnS), tin oxide, aluminum oxide (AlO_3), zinc oxide, calcium sulfate, barium sulfate, calcium carbonate, antimony oxide, sodium silicate, aluminum silicate, silica, mica, clay, and the like.

[0030] In a preferred embodiment the IR reflective agent is a mixed metal oxide type chosen from the group of the rutile (MeO2), hematite (Me2O3), or spinel (Me3O4) type with metals comprising: cobalt, iron, trivalent chrome, tin, antimony, titanium, manganese and aluminum.

[0031] The reflective agent is used in an amount from 0.01 wt% to 8.0 wt%, preferably from 0.3 wt% to 5.0 wt%, more preferably from 0.3 wt% to 3.0 wt% based on the total fiber weight.

[0032] Another aspect of the present invention is directed to an artificial turf comprising a plurality of the artificial turf fibers securely attached to a backing material. Preferably, at least a percentage of the plurality of the artificial turf fibers

form closed loops extending above a top surface of the backing of the artificial turf. In a more preferred embodiment, all of the plurality of the artificial turf fibers form closed loops extending above the top surface of the backing of the artificial turf. It has been found that the fiber closed loops are particularly suitable for further increasing the smoothness of the turf fibers and are particularly suited for surfaces of fields of sports such as hockey.

[0033] In another preferred embodiment, the fibers are texturized which further enhances the ability of the fibers to dissipate heat and improves their overall look and mechanical characteristics such as their overall smoothness.

[0034] According to embodiments, the fibers are strongly texturized, thereby increasing the smoothness of the artificial turf surface and making the surface more similar to a wetted artificial turf surface even when water is absent. A "texturized" fiber is a fiber with a shape memory which returns, when released, to a non-straight, e.g., curly, crumpled, folded, and/or twisted shape.

[0035] According to embodiments, the artificial turf fibers are integrated into the backing and have a density (number of fibers per artificial turf area) and/or degree of texturization that under a bird's eye perspective, at least 60%, more preferentially at least 70% of the size of the area covered by the artificial turf consists of the fibers and the rest consists of the backing or the infill. In a preferred embodiment the turf structure is typically in analogy to the water-filled high pile weight hockey infill-free.

[0036] In yet another preferred embodiment, the part of the fibers extending above the backing is wholly or partially texturized. A texturized fiber means that at least a part of the fiber which extends above the backing material instead of being straight it has at least one of a curl or a wave shape. The curls or waves can be produced mechanically or chemically during the manufacturing of the fiber.

[0037] The backing of the artificial turf is made of a thermoset polymer material. The thermoset material may include, for example, a polyurethane resin.

[0038] In yet another aspect of the present invention, a method of fabricating the artificial turf is provided, the method comprising,

forming a polymer mixture comprising at least one polymer, an anti-slip agent, and preferably also reflective particle,
feeding the polymer mixture to an extruder to form a monofilament,
quenching the monofilament,
reheating the monofilament, and
stretching the reheated monofilament to form a monofilament,
then, bundling a plurality of monofilaments to form an artificial turf fiber, and
incorporating the artificial turf fiber into a backing to form the artificial turf.

[0039] In an embodiment, incorporating the turf fiber into the carrier includes positioning the fiber so that a first fraction of the fiber is located at the back side of a carrier (also referred to hereinafter as the back fraction of the fiber), a second fraction of the fiber is protruding to the front side of the carrier (also referred to hereinafter as the front fraction of the fiber) and a third fraction of the fiber is inside the carrier (referred to also as the middle fraction of the fiber or the carrier portion of the fiber).

[0040] According to a particular referred embodiment, the backing of the artificial turf incudes a biocide agent (also referred to as antimicrobial agent) which is a zinc-based antimicrobial agent or a metal coordination complex with pyrithione. The use of the biocide agent in the backing of the artificial turf prevents microbial infestation of the turf which in combination with the reduced need for watering of the inventive artificial turf fiber provide a significant improvement over existing artificial turfs for hockey fields which require extensive watering and therefore they are prone to microbial infestation.

[0041] Examples of suitable metal coordination complexes with pyrithione that can serve as antimicrobial agents include zinc pyrithione, manganese pyrithione, copper pyrithione, and sodium pyrithione. Examples of suitable zinc-based antimicrobial agents other than zinc pyrithione include zinc oxide nanoparticles and a zinc-glucose-citrate complex. Particularly preferred is pyrithione zinc (also often referred to commonly as zinc pyrithione).

[0042] The pyrithione zinc is used as the antimicrobial agent in an amount of 0.05 wt% to 1.5 wt%, of the polyurethane reaction mixture, and, preferably, in an amount of 0.08 wt% to 0.7 wt % of the polyurethane reaction mixture. More preferably, the zinc pyrithione is used as the antimicrobial agent in an amount of 0.1 wt% to 0.5 wt% of the polyurethane reaction mixture. The use of the pyrithione zinc in the backing of an artificial turf is described in a co-pending United States patent application of the same applicant with application no. 63/345,549 filed on May 25, 2022 with the US patent and trademark office an which is incorporated herein for its disclosure of the use of the biocide agent in a polyurethane backing of an artificial turf.

[0043] In a preferred embodiment the fiber used is a texturized monofilament with a texturization degree after 5 min at 90°C of 25-40 %.

[0044] In a most preferred embodiment the monofilament fiber has after 5 minutes at 90°C a texturization degree of 32 to 37 % and is chosen from a triangle, quadrangle or oval shaped form and a mixture thereof.

[0045] According to several embodiments, the artificial turf is infill free.

[0046] In further embodiments the artificial turf is either sand dressed or sand filled.

[0047] In a further embodiment the artificial turf is filled with an elastomeric material chosen from the group of styrene-butadiene rubber, natural butadiene rubber, thermoplastic elastomer (TPE) like styrenic block copolymers, whereby the infill can preferably comprise a reflective agent, which is based on mixed metal oxides.

[0048] Yet another aspect of the present invention is directed to the use of the artificial turf in a hockey field that is according to the standard of the International Federation of Hockey known by the acronym FIH. Because of the continuous reduction of the fiber friction coefficient of the surface of the artificial turf fibers, watering of the surface of the artificial turf field can be reduced substantially or even become unnecessary.

[0049] Although the precise mechanism of the migration of the anti-slip agent in the polymer material and its interaction with the reflective particles is not fully understood, it has been found rather surprisingly that the anti-slip agent and in particular the erucic acid amide and like type fatty acid amides migrate slowly from an interior to the surface of the fiber, where they accumulate and replace the lost anti-stick agent due to normal wear and abrasion of the fiber over an unexpectedly prolonged period of time. For the claimed combination of polymer material, anti-slip agent and preferably of the reflective agent the reduction of the friction coefficient reduction of the fibers can last for the typical useful life of the artificial turf which may range from 10 to 15 years.

[0050] These and other features and advantages of the present invention will become better understood from the following detailed description of the invention in conjunction with the accompanying drawings.

Brief Description of the Drawings

[0051] In the following, embodiments of the invention are explained in greater detail, by way of example only, making reference to the drawings in which:

Fig. 1 shows a flowchart which illustrates an example of a method of manufacturing artificial turf;
Fig. 2a shows a diagram which illustrates a cross-section of a polymer mixture;
Fig. 2b shows a further example of a polymer mixture;
Fig. 3 shows a further example of a polymer mixture;
Fig. 4 illustrates the extrusion of the polymer mixture into a monofilament;
Fig. 5 shows the tufting of an artificial turf fiber;
Fig. 6 illustrates first and second parts of the fiber; and
Fig. 7 shows the first parts and portions of second parts of the fibers embedded in the turf backing.

Detailed Description of the Invention

[0052] The present invention provides an artificial turf fiber comprising a polymer material and an anti-slip agent incorporated/contained in the polymer material in an amount adequate to last for at a least one year of slow migration from the interior to the surface of the fiber. The fiber polymer material and the anti-slip agent are selected to allow slow diffusion of the anti-slip agent towards the surface of the artificial turf fiber, where they accumulate and replace the lost anti-slip agent due to normal wear and abrasion of the fiber. The anti-slip agent is added in the fiber in an effective amount designed to last reducing the friction coefficient of the fibers preferably for a period of at least 5 years, more preferably at least 10 years, and most preferably at least 15 years.

[0053] Although we do not wish to be bound by theory, key factors which are believed to control the diffusion of the anti-slip agent to the surface of the fiber include for the anti-slip agent, the type of the anti-slip agent, the size of the anti-slip agent, and the hydrophilicity of the anti-slip agent, while for the polymer material include the type, and density of the polymer material. Through extensive research and consideration of the above factors, the polymer material for the fiber, the anti-slip agent, and preferably the reflective agent and their relative amounts were selected.

[0054] In a specific embodiment the EEA is used in an amount of 0.5 wt% based on the total weight of the turf fiber. The turf fiber may be made of a mixture of 10 wt% LDPE and 90 wt% LLDPE of the holistic polymer weight. In another embodiment the EEA is used in an amount of 1.0 wt% based on the total weight of a turf fiber made of the mixture of LDPE and LLDPE. In yet another embodiment the EEA is used in an amount of 1.5 wt% based on the total weight of the mixture of LDPE and LLDPE. In yet another embodiment the EEA is used in an amount of 1.0 wt% based on the total weight of a turf fiber made of a mixture of 15 wt% HDPE (density of 0.955 g/cm^3) and 85 wt% LLDPE (density of 0.920 g/cm^3).

[0055] Preferably, the fiber also includes a reflective agent such as reflective particles, and/or reflective pigments for preventing overheating of the fiber.

The Artificial Turf

[0056] An example of a method for manufacturing the artificial turf comprises incorporating the artificial turf fiber into a carrier, and adding a viscous thermoset resin reaction mixture onto a back side of the carrier to form a thermoset resin backing. Various additives may be added in the thermoset reaction mixture including, for example, a biocide agent having antimicrobial, antibacterial and antifungal properties. Once the thermoset resin reaction mixture is placed on the back side of the carrier, hardening of the thermoset reaction mixture is performed to form a solid thermoset resin backing with a portion of the turf fiber which protrudes out of the back side of the carrier being securely embedded inside the solid mass of the thermoset resin backing. The thermoset resin may be any suitable resin. Preferably, the thermoset resin may be a polyurethane resin. In an embodiment, the polyurethane is the reaction product of first and second polyols with an isocyanate, wherein the first polyol is polyether polyol and/or polyester polyol having at least two ("2") hydroxyl groups per molecule, wherein the second polyol is polybutadiene diol, wherein the isocyanate comprises isocyanate monomers, isocyanate polymers or isocyanate prepolymers or a mixture thereof, and wherein the isocyanate monomers, the isocyanate polymers and the isocyanate prepolymers have two or more isocyanate groups per molecule. The polybutadiene diol may be used in an amount of 0.5-10% by weight of a combination of the first polyol and the isocyanate, and may have a number average molecular weight in the range of 500 to 6000 g/mol, more preferably in the range of 1.500 to 4.500 g/mol. The polyurethane reaction mixture may further comprise a surfactant and other additives and fillers. The hardening of the fluid polyurethane mass can be performed, for example, by heating the polyurethane reaction mixture on the back side of the carrier to a temperature of 70-140°C.

[0057] The making of the turf fiber includes forming a polymer material mixture inside a first container, preparing an additive mixture including the anti-slip agent, and preferably also the reflective agent and optionally various other additives for the fiber in a separate or a plurality of separate smaller containers, mixing the polymer material mixture with the additive mixture to form an extrusion feed mixture that is fed to an extruder to form a monofilament (in actuality, typically a plurality of monofilaments). The monofilament exiting from the extruder is quenched, for example, by passing it through a water bath, and upon exiting from the water bath the monofilament is reheated, for example, in an air oven. The reheated monofilament is oriented by stretching the reheated monofilament to form an oriented monofilament which is used as the artificial turf fiber either individually or after being combined with other monofilaments. For example, through a well-known process multiple monofilaments may be combined to form an artificial turf fiber which can be rolled into a yarn. The anti-slip agent and preferably also the reflective agent may be added in the additive mixture inside the smaller container. However, this is just an example, and it should be understood that the anti-slip agent can be added also in the larger container directly with the polymer material mixture or as a separate feed to the extruder feed. The polymer mixture may further comprise a nucleating agent for crystallizing the polymer within and at the surface of the monofilament anti UV agents, anti-flame agents and other optional additives. The artificial turf fiber is typically a bundle of at least 5 monofilaments.

[0058] The reflective agent (e.g., reflective particles and/or a reflective pigments) are used for counteracting the overheating of the turf. These reflective particles and reflective pigment have the advantage of cooling the artificial turf field, thereby compensating the missing cooling effect of the water when water is absent. Also, applicant has found that the type and amount of the reflective agent may affect the effective rate of migration of the anti-slip agent in the polymer material matrix of the fiber.

[0059] The polymer material mixture and the additive mixture including the anti-slip agent, preferably also the reflective agent may be blended using a blender or mixing device prior to add them to the extruder.

[0060] The term "tufting" as used herein refers to a method of incorporating a fiber into an existing carrier. Short U-shaped loops of fibers are introduced through the carrier from one side so that their ends point outside of the carrier in the other direction. Usually, the tuft yarns form a regular array of "dots" on the other side. On the one side of the carrier where the U-shaped loops are located, the tuft fibers may be tied for security, although they need not be. The ends of the tuft yarns can then optionally be frayed or otherwise processed, so that they will subsequently create a dense layer of fibers protruding from the carrier.

[0061] The term "weaving" as used herein is a method of incorporating an artificial turf fiber (which can be a monofilament or a bundle of monofilaments) into an existing carrier, whereby the artificial turf fiber and the fiber(s) that built the carrier are interlaced. The interlaced fibers and the mesh form a fabric like or cloth like structure. When an artificial tuft fiber is incorporated by weaving, the fiber interlaces a series of mesh fibers at least three times. Thus, when a fiber is incorporated by weaving rather than tufting, a higher fraction of the artificial turf fiber is interlaced in the carrier material. This may increase the resistance to wear and tear of the artificial turf.

[0062] According to embodiments, incorporating the artificial turf fiber into the carrier comprises: tufting the artificial turf fiber into the carrier. According to alternative embodiments, incorporating the artificial turf fiber into the carrier comprises weaving the artificial turf fiber into the carrier.

[0063] Referring now to figure 1 a flowchart is provided which illustrates an example of a method of manufacturing artificial turf. First in step 102 a polymer mixture such as the mixture 200 depicted in figure 2a is created. The polymer

mixture 200 comprises at least one polymer 204, an anti-slip agent 202, and preferably a reflective agent 208 (e.g., reflective particles 208) for providing continuous reduction of the friction coefficient of the fibers for at least one year, preferably at least 5 years, more preferably at least 10 years, and most preferably at least 15 years.

[0064] The polymer mixture may be created by putting all of the components that make it up together at once. For instance, the at least one polymer 204, the anti-slip agent 202, the reflective agent 208 and the optional additives 206 could be all added together at the same time. The polymer mixture could be thoroughly mixed for instance by using a mixer device. The desired distribution of the components can be achieved by using the proper rate or amount of mixing. The generated mixture could be forwarded to a one-screw feed or a two-screw feed for the extrusion.

[0065] Additional optional substances may be added. Also, a reflective pigment 302 may be used in addition or instead of the reflective particles as shown in figure. 3.

[0066] In step 104, the polymer mixture is extruded into a monofilament 506 as illustrated in figure 4. Next in step 106 the monofilament is quenched or rapidly cooled down. In step 108 the monofilament is reheated and in step 110 the reheated monofilament is stretched to form a monofilament that can directly be used as an artificial turf fiber or that can be bundled with additional monofilaments into an artificial turf fiber. Additional steps may also be performed on the monofilament to form the artificial turf fiber. For instance, the monofilament may be spun or woven into a yarn with desired properties. Next in step 112 the artificial turf fiber is incorporated into an artificial turf backing. The incorporation comprises a step 114 of arranging a plurality of the artificial turf fibers on a carrier 704 (see figure 6 and 7). The carrier may be a textile plane, for example. The artificial turf fibers are arranged such that first parts 706 of the monofilaments are exposed to a bottom side of the carrier and second parts 702 of said monofilaments are exposed to a top side of the carrier. The arranging could be accomplished by tufting or weaving the artificial turf fiber into the carrier, but other methods of arranging the fibers within the carrier are also possible.

[0067] Then in step 116 a resin reaction fluid mixture is added on the bottom side of the carrier such that at least the first parts become embedded in the fluid. Finally, in step 118, the fluid mixture is caused to solidify into a film. The film surrounds and thereby mechanically fixes at least the first parts 706 (and optionally also some portions 804 of the second parts 702) of the monofilaments in the film. The film, i.e., the solidified fluid, constitutes the backing 802.

[0068] Figure 2a shows a cross section of a polymer mixture 200 comprising at least a first polymer 204, preferentially a non-polar polymer such as polyethylene, and an anti-slip agent 202 such as EEA. The polymer mixture may further comprise additives 206 such as a dye for coloring the fiber, a biocide for adding antimicrobial property, a nucleating agent, and the like. The anti-slip agent 202 is added in an adequate amount and should have a slow migration rate within the polymer material matrix of the fiber so that it can last replenishing the surface of the fiber with the anti-slip agent for at least one year, preferably at least 5 years, more preferably at least 10 years and most preferably at least 15 years. In the illustrated example, the at least one polymer is a mixture of LDPE, and LLDPE, wherein the LDPE is 10 wt% and LLDPE is 90 wt% of the total polymer mixture of LDPE and LLDPE. The anti-slip agent 202 is, for example, EEA and is used in an amount of 0.5 wt% based on the total weight of the fiber, i.e., including the polymer, the anti-slip agent, and the additives.

[0069] Figure 2b shows a polymer mixture 250 comprising all the components of the mixture 200 of figure 2a and in addition a reflective agent 208. The reflective agent 208 is, for example, titanium dioxide and is used in an amount of 1.0 wt% based on the total amount of the polyethylene, the EEA, and the optional additives. Said reflective agent 208 prevents overheating of the fiber and thus further reduce the need for frequent watering of the turf. Although, the precise mechanism is not well understood, the presence of the reflective agent (i.e., the reflective pigment and or the reflective particles) in the polymer matrix of the fiber and their respective amounts may affect the migration rate of the anti-slip agent inside the polymer matrix of the fiber. Thus, the amount of the reflective agent in the fiber is controlled for obtaining a migration rate for the anti-slip agent that ensures that the anti-slip agent can last reducing the friction coefficient of the fibers, most preferably, for the useful life of the artificial turf. This is a rather unexpected and surprising synergistic effect between the anti-slip agent and the reflective agent.

[0070] Figure 3 shows a cross section of a polymer mixture 300 comprising at least a first polymer 204, e.g., the LDPE/LLDPE mixture described above, and the anti-slip agent 302.

[0071] Figure 4 illustrates the extrusion of the polymer mixture into a monofilament 506. Shown is a schematic simplified cross-sectional view of an amount of the polymer mixture 200. Within the polymer mixture 200 there is dispersed the anti-slip agent 202 (e.g., EEA) in an effective amount and optionally also additional additives 206. Preferably, the additives 206 also include a reflection agent as discussed above. A screw, piston or other device is used to force the polymer mixture 200 through a hole 502 in a plate 504. This causes the polymer mixture 200 to be extruded into a monofilament 506. The monofilament 506 is shown as containing the anti-slip agent 202 and the additives 206 (preferably also including the reflective agent) also.

[0072] Figures 5 and 6 show how a plurality of artificial turf fibers can be arranged in a carrier 704, e.g., a textile plane, by means of tufting. Tufting is a type of textile weaving in which an artificial turf fiber 701 (that may be a monofilament 506 or a bundle of multiple monofilaments) is inserted on a carrier 704. After the inserting is done, as depicted in Fig. 5, short U-shaped loops of the fiber point outside of the carrier's surface. Then, one or more blades cut 602 through the

loops. As a result of the cutting step, two artificial turf fiber ends per loop and monofilament point out from the carrier and a grass-like artificial turf surface is generated. Thereby, first parts 706 of the monofilaments of the artificial turf fibers having been inserted in the carrier 704 are exposed to a bottom side of the carrier and second parts 702 of said monofilaments are exposed to a top side of the carrier.

[0073] In a preferred embodiment for artificial turf for hockey fields the cutting step 602 is omitted and the artificial turf is made with the U-shaped loops forming the top surface of the turf.

[0074] Figure 7 depicts the carrier 704 with the inserted filaments having been embedded within (Fig. 7a) or next to a surface of (Fig. 7b) an artificial turf backing 802. This is performed by adding a fluid in step 116 (see Fig. 1) on the carrier 704 such that the first parts 706 of the monofilaments become embedded in the fluid (Fig. 7a) or the first parts and some portions 804 of the second parts 702 of the monofilaments (Fig. 7b) become embedded in the fluid. The carrier may be a textile mesh or may comprise perforations that allow the fluid 802.2 at the bottom side of the carrier to flow to the upper side of the carrier and vice versa, thereby creating a portion 802.1 of the backing on top of the carrier. Thus, the carrier and parts of the fibers inserted in the carrier may become embedded in the backing 802. The artificial turf fibers 701 are shown as extending a distance 806 above the carrier 704. The distance 806 is essentially the height of the pile of the artificial turf fibers 701.

[0075] For example, the fluid may be a styrene-butadiene suspension that solidifies into a latex backing or, preferably, may be a mixture of polyols and polyisocyanates that solidifies into a polyurethane backing or any other kind of fluid that is capable of solidifying after a defined time period into a solid film. The fluid solidifies into a film 802, e.g., by a drying process or by a chemical reaction resulting in a solidification of the fluid. Such a chemical reaction can be, for example, a polymerization. The film surrounds and thereby mechanically fixes at least the first parts of the monofilaments of the arranged artificial turf fibers. The solid film acts as the artificial turf backing. In some examples, additional coating layers may be added on the bottom of the artificial turf backing.

Examples

[0076] In Example 1 0.5 wt% of EEA anti-slip agent was added in a polymer mix of 60 wt% LDPE and 40 wt% LLDPE. The LDPE had a density of 0.905 g/cm^3 and the LLDPE had a density of 0.918 g/cm^3 and was a copolymer of polyethylene and butene. No reflective agent was added. Additives such as color pigments, flame retardants were also added and the mixture was extruded in a conventional extrusion equipment to form an artificial turf fiber which was then added in an artificial turf structure having a polyurethane backing as described above with reference to the figures.

[0077] In examples 2-5 the same process was repeated with the key parameters shown in Table 1. In examples, 2-5 the fiber was texturized to have a top at least about 30 % of its length which extends above the backing and any infill material in the shape of a wave. Compared to example 1 which comprised straight fibers, the turf made with the texturized fibers of examples 2 and 5 showed significant improvement in its overall smoothness and coverage.

[0078] The same process was repeated in total 5 times with the key compounds added each time shown in Table 1 below.

Table 1

	Ex. 1	EX. 2	Ex. 3	Ex. 4	Ex. 5
Polymer 1	LLDPE	LLDPE	HDPE	LLDPE	LLDPE
Polymer 1 density	0.918	0.918	0.94	0.918	0.918
Polymer 1 WT%	60	20	100	70	30
Polymer 2	LLDPE	LLDPE	--	HDPE	HDPE
Polymer 2 density	0.920	0.920	--	0.94	0.94
Polymer 2 Wt%	40	80	--	30	70
antistatic	EEA	EEA	EEA	EEA	EEA
Anti-static agent amount wt%	0.5	0.5	0.5	0.5	0.5
Reflective Agent	NO	TITANIUM DIOXIDE	TITANIUM DIOXIDE	Mixed metal oxide	Mixed metal oxide
Reflective agent amount wt%		1.0	1.0	1.0	1.0

(continued)

	Ex. 1	EX. 2	Ex. 3	Ex. 4	Ex. 5
Fiber texturization	NO	Yes, type waves 30%	Yes, type waves 30%	Yes, type waves 30%	Yes, type waves 30%

[0079] The above formed fibers in examples 1-5 were tested and compared with the comparative examples 6-10.

[0080] Significant improvement in the overall smoothness and tribological characteristics was observed between the examples 1-5 and their corresponding comparative examples 6-10. A significant reduction in the friction coefficient was observed in the examples 1-5 compared to their corresponding comparative examples 6-10 of at least 10%.

[0081] In comparative examples 6-10 the same fiber compositions as in examples 1-5 were used except that no anti-slip agent was used in the polymer mixtures.

[0082] Although the invention has been described in reference to specific embodiments, it should be understood that the invention is not limited to these examples only and that many variations of these embodiments may be readily envisioned by the skilled person after having read the present disclosure which do not fall outside the scope of the invention as defined by the claims.

List of reference numerals

[0083]

102-118	process steps
200	put in the mixture
202	anti-slip agent
204	polymer
206	further additive substances
208	reflective particles or reflective pigment
300	polymer mixture
502	hole in a plate
504	plate
506	monofilament of artificial turf fiber
602	cutting artificial turf fibers during tufting
701	artificial turf fiber
702	second parts of fibers
704	carrier
706	first parts of fibers first parts of fiber
800	artificial turf (cross-section)
802	backing made from solidified fluid
804	portions of the second parts of the fibers embedded in the fluid
806	distance <carrier-surface - upper ends of fibers>

Claims

1. An artificial turf fiber comprising a polymer material and an anti-slip agent incorporated/contained in the polymer, **characterized in that** the anti-slip agent has an effective rate of migration in the polymer material and is provided in the polymer material in an effective amount to provide effective reduction of the fiber friction coefficient on the surface of the fiber for at least one year, preferably for at least 2 years, more preferably for at least 5 years, and most preferably for at least 10 years.

2. The artificial turf fiber of claim 1, wherein the polymer material is selected from the group consisting of polyolefin homopolymers, polyolefin random copolymers, preferably polyethylene including low density polyethylene (LDPE), linear low-density polyethylene (LLDPE), and/or high-density polyethylene (HDPE) and mixtures thereof.

3. The artificial turf fiber of claim 1 or 2, wherein the polymer material is a mixture of LDPE and LLDPE, or a mixture of LLDPE and HDPE, wherein preferably the amount of LLDPE in the polymer material mixture is greater than the amount of the LDPE or the amount of HDPE.

4. The artificial turf fiber of claim 1 or 2, wherein the polymer material is a mixture of LDPE, and LLDPE, wherein the LLDPE is preferably from 10 to 70 wt% of the polymer material, more preferably from 15 to 50% wt%, and more preferably from 25 to 45 % of the total amount of LDPE and LLDPE, wherein preferably the amount of LLDPE in the polymer material mixture is greater than the amount of the LDPE.

5. The artificial turf fiber of any of claims 1-2, wherein the polymer material is a mixture of HDPE and LLDPE, wherein the HDPE has a density of 0.952 to 0.957 g/cm^3 and is in an amount of 5.0 to 18 wt%, preferably 12 to 17 wt% of the total amount of HDPE and LLDPE.

6. The artificial turf fiber of any of the claims 1-5, wherein the anti-slip agent is selected from the group consisting of fatty acid amides, and stearates.

7. The artificial turf fiber of any of the claims 1-6, wherein the anti-slip agent is used in an amount of from 0.05 to 1.0 wt%, preferably in an amount of from 0.1 to 0.7 wt%, and more preferably from 0.2 to 0.6 wt% based on the total weight of the fiber.

8. The artificial turf fiber of any of the claims 1-7, wherein the anti-slip agent is erucic acid amide.

9. The artificial turf fiber of any of the claims 1-8, further comprising reflective particles and or reflective pigments for preventing overheating of the fiber.

10. The artificial turf fiber of any of the claims 1-9, wherein the fiber is texturized with at least 30% of the part of the fiber length which extends above the infill material having at least one of curl, or wave shape for enhanced softness and coverage.

11. An artificial turf comprising a plurality of the artificial turf fibers of any of the claims of 1-10 securely attached to a backing material, and wherein the plurality of artificial turf fibers form closed loops extending above a top surface of the backing.

12. The artificial turf of claim 11, wherein the fibers are texturized fibers, and wherein the density of the fibers is at least 60%, more preferentially at least 70% of the area covered by the artificial turf.

13. The artificial turf of any of the claims 11-12, wherein the backing includes a biocide agent which is a zinc-based antimicrobial agent or a metal coordination complex with pyrithione, preferably pyrithione zinc.

14. The use of the artificial turf of any of the claims 11-13 in a hockey field, wherein watering of the hockey field is reduced substantially or becomes totally needless.

15. A hockey field playing surface comprising the artificial turf of any of the claims 11-14, wherein watering of the hockey field is reduced substantially or becomes totally needless and is substantially free of microbial infestation for the useful life of the artificial turf.

Amended claims in accordance with Rule 137(2) EPC.

1. An artificial turf fiber comprising a polymer material and an anti-slip agent selected from the group consisting of fatty amides and stearates incorporated/contained in the polymer, **characterized in that** the anti-slip agent has an effective rate of migration in the polymer material and is provided in the polymer material in an amount of from 0.05 to 1.0 wt% based on the total weight of the fiber to provide a reduction of the fiber friction coefficient on the surface of the fiber for at least one year, preferably for at least 2 years, more preferably for at least 5 years, and most preferably for at least 10 years, wherein the polymer material is selected from the group consisting of polyolefin homopolymers, and polyolefin random copolymers.

2. The artificial turf fiber of claim 1, wherein the polymer material is selected from the group consisting of preferably polyethylene including low density polyethylene (LDPE), linear low-density polyethylene (LLDPE), and/or high-density polyethylene (HDPE) and mixtures thereof.

3. The artificial turf fiber of claim 1 or 2, wherein the polymer material is a mixture of LDPE and LLDPE, or a mixture

of LLDPE and HDPE, wherein preferably the amount of LLDPE in the polymer material mixture is greater than the amount of the LDPE or the amount of HDPE.

4. The artificial turf fiber of claim 1 or 2, wherein the polymer material is a mixture of LDPE, and LLDPE, wherein the LLDPE is preferably from 10 to 70 wt% of the polymer material, more preferably from 15 to 50% wt%, and more preferably from 25 to 45 % of the total amount of LDPE and LLDPE, wherein preferably the amount of LLDPE in the polymer material mixture is greater than the amount of the LDPE.

5. The artificial turf fiber of any of claims 1-2, wherein the polymer material is a mixture of HDPE and LLDPE, wherein the HDPE has a density of 0.952 to 0.957 g/cm^3 and is in an amount of 5.0 to 18 wt%, preferably 12 to 17 wt% of the total amount of HDPE and LLDPE.

6. The artificial turf fiber of any of the claims 1-5, wherein the anti-slip agent is a fatty acid amide.

7. The artificial turf fiber of any of the claims 1-6, wherein the anti-slip agent is used preferably in an amount of from 0.1 to 0.7 wt%, and more preferably from 0.2 to 0.6 wt% based on the total weight of the fiber.

8. The artificial turf fiber of any of the claims 1-7, wherein the anti-slip agent is erucic acid amide.

9. The artificial turf fiber of any of the claims 1-8, further comprising reflective particles and or reflective pigments for preventing overheating of the fiber.

10. The artificial turf fiber of any of the claims 1-9, wherein the fiber is texturized with at least 30% of the part of the fiber length which extends above the infill material having at least one of curl, or wave shape for enhanced softness and coverage.

11. An artificial turf comprising a plurality of the artificial turf fibers of any of the claims of 1-10 securely attached to a backing material, and wherein the plurality of artificial turf fibers form closed loops extending above a top surface of the backing.

12. The artificial turf of claim 11, wherein the fibers are texturized fibers, and wherein the density of the fibers is at least 60%, more preferentially at least 70% of the area covered by the artificial turf.

13. The artificial turf of any of the claims 11-12, wherein the backing includes a biocide agent which is a zinc-based antimicrobial agent or a metal coordination complex with pyrithione, preferably pyrithione zinc.

14. The use of the artificial turf of any of the claims 11-13 in a hockey field, wherein watering of the hockey field is reduced substantially or becomes totally needless.

15. A hockey field playing surface comprising the artificial turf of any of the claims 11-14, wherein watering of the hockey field is reduced substantially or becomes totally needless and is substantially free of microbial infestation for the useful life of the artificial turf.

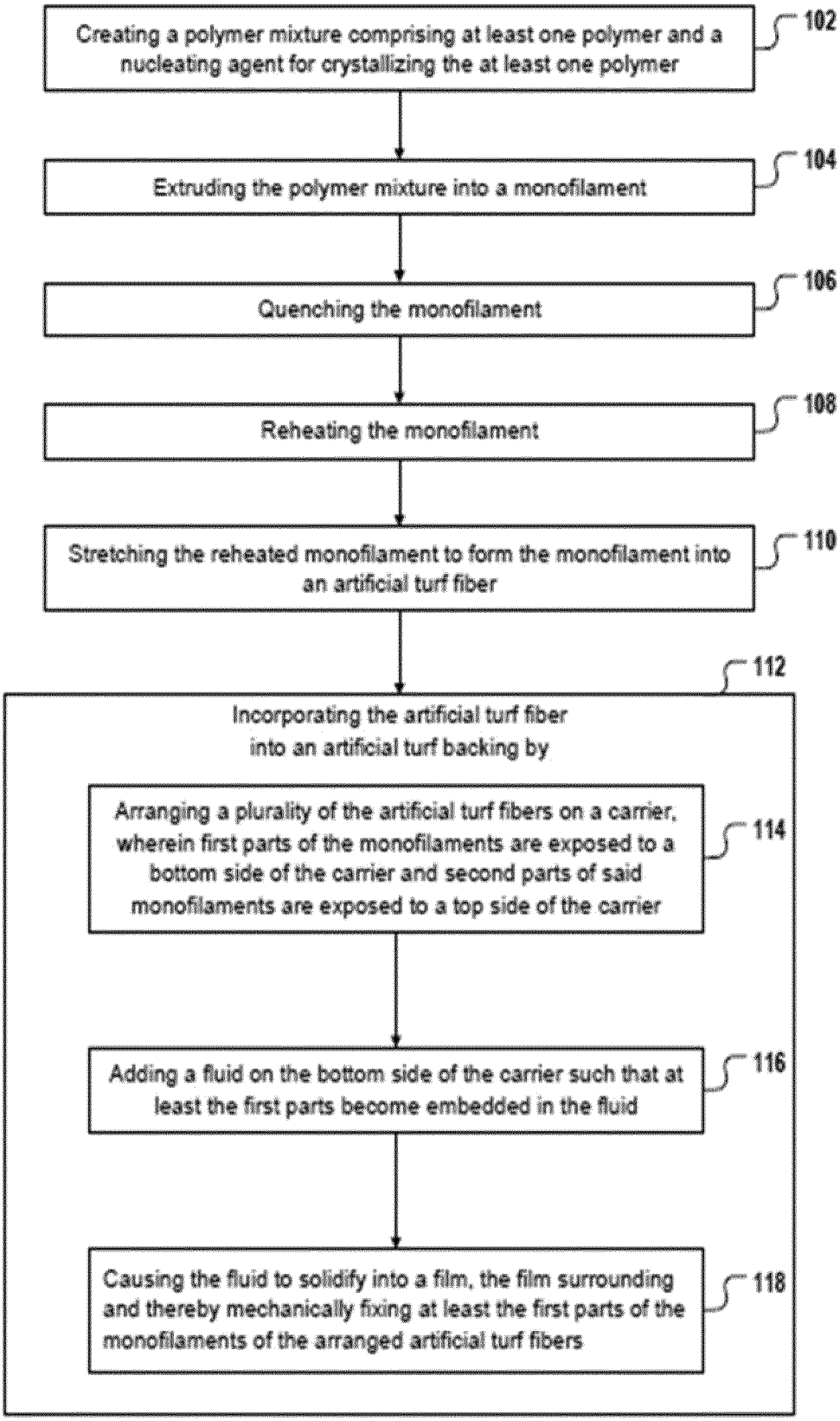
Creating a polymer mixture comprising at least one polymer and a nucleating agent for crystallizing the at least one polymer
102
Extruding the polymer mixture into a monofilament
104
Quenching the monofilament
106
Reheating the monofilament
108
Stretching the reheated monofilament to form the monofilament into an artificial turf fiber
110
112
Incorporating the artificial turf fiber into an artificial turf backing by
Arranging a plurality of the artificial turf fibers on a carrier, wherein first parts of the monofilaments are exposed to a bottom side of the carrier and second parts of said monofilaments are exposed to a top side of the carrier
114
Adding a fluid on the bottom side of the carrier such that at least the first parts become embedded in the fluid
116
Causing the fluid to solidify into a film, the film surrounding and thereby mechanically fixing at least the first parts of the monofilaments of the arranged artificial turf fibers
118

Fig. 1

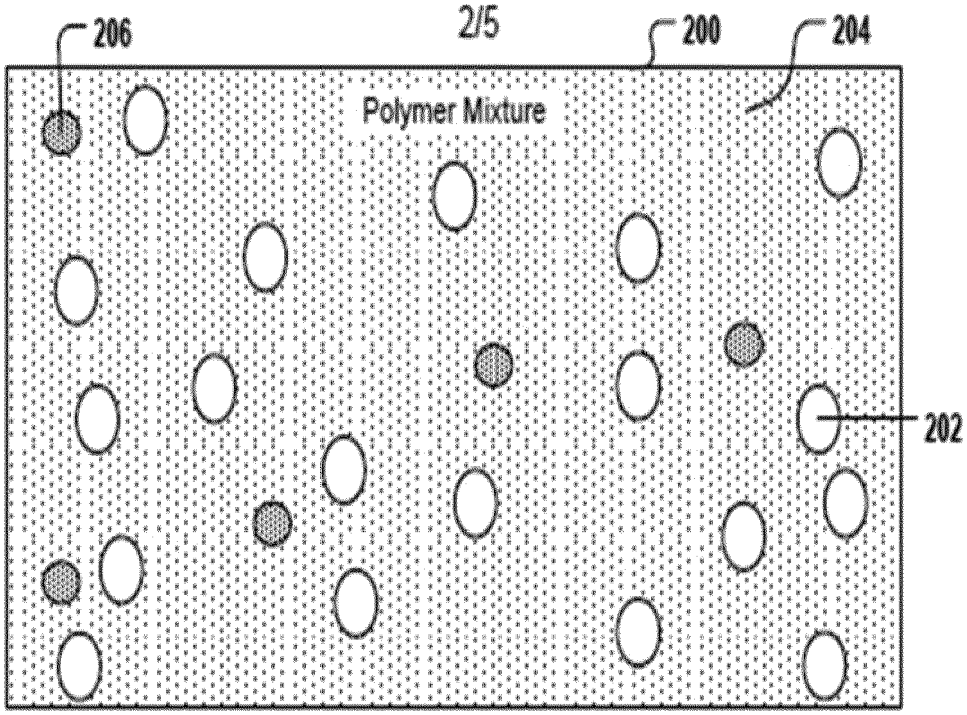
206
200
204
Polymer Mixture
202

Fig. 2a

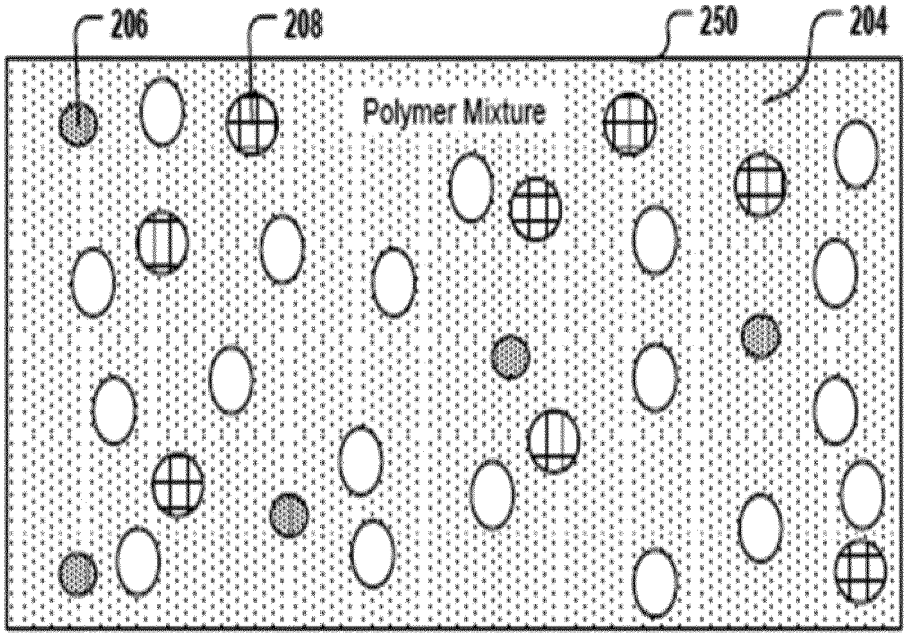
206
208
250
204
Polymer Mixture

Fig. 2b

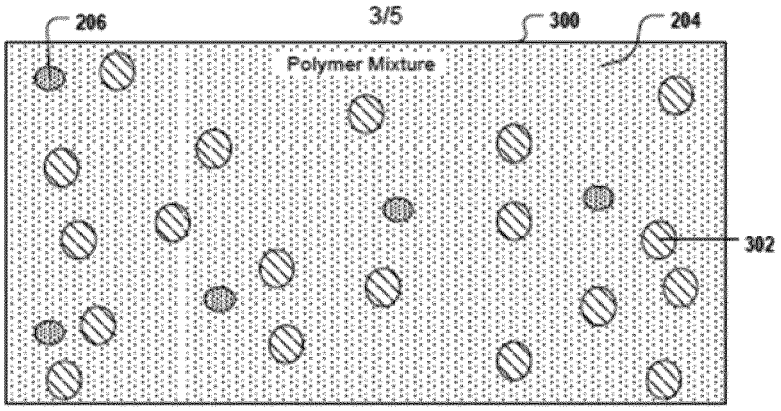
206
300
204
Polymer Mixture
302

Fig. 3

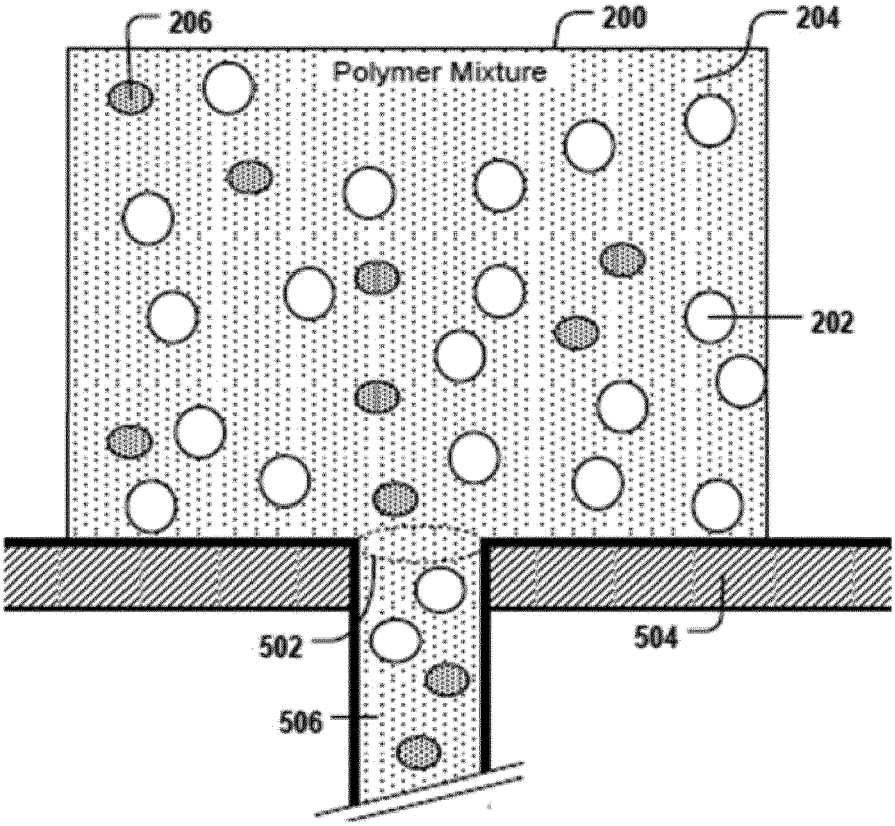
206
200
204
Polymer Mixture
202
502
504
506

Fig. 4

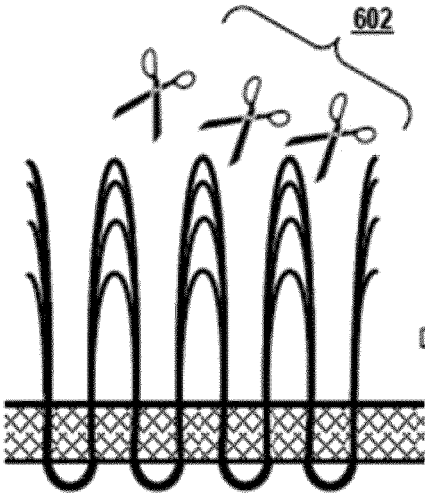

Fig. 5

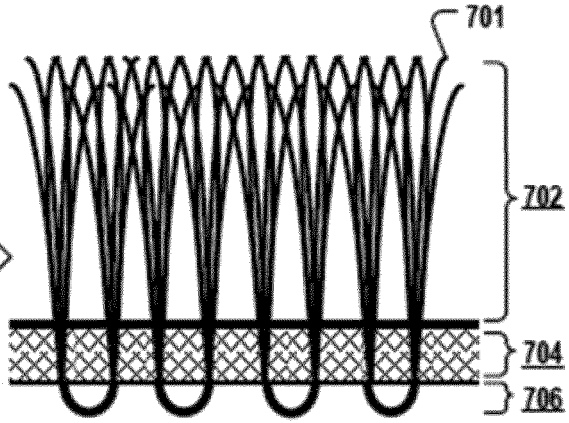

Fig. 6

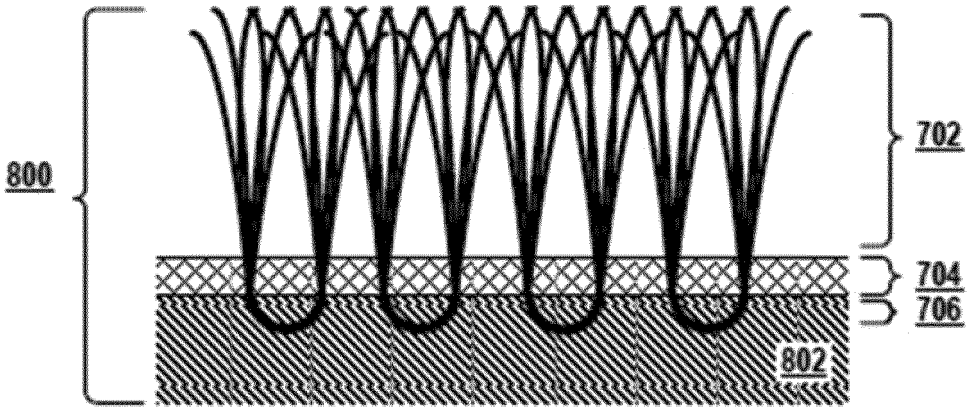

Fig. 7A

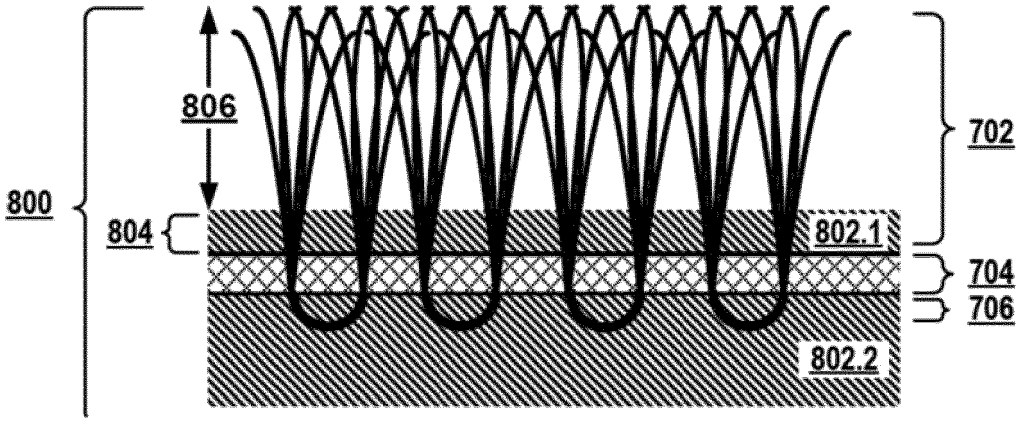

Fig. 7B

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EUROPEAN SEARCH REPORT

Application Number
EP 22 17 7277

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	GB 2 601 243 A (DON & LOW LTD [GB]) 25 May 2022 (2022-05-25) * page 5, lines 5-16; claims 1-26; figures 1-3,4,5 * * page 19, line 10 - page 20, line 11 *	1-5,9-15	INV. D01F1/10 D01F6/04 D01F6/46 E01C13/08
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X	CN 102 493 011 A (TAISHAN SPORTS INDUSTRY GROUP ET AL.) 13 June 2012 (2012-06-13) * claims 1-8; figure 1; examples 1-3 *	1-15	
X	KR 102 157 036 B1 (KOLON GLOTECH INC [KR]) 18 September 2020 (2020-09-18) * abstract; claims 1,2,4,6-8 * * paragraphs [0027] - [0050] *	1-15	
X	CN 111 364 113 A (ALL VICTORY GRASS GUANGZHOU CO LTD) 3 July 2020 (2020-07-03) * claims 1-8 *	1-15	TECHNICAL FIELDS SEARCHED (IPC) D01F E01C
A	CHEN J ET AL: "Fundamental study of erucamide used as a slip agent", JOURNAL OF VACUUM SCIENCE, AMERICAN INSTITUTE OF PHYSICS, 2 HUNTINGTON QUADRANGLE, MELVILLE, NY 11747, vol. 25, no. 4, 2 July 2007 (2007-07-02), pages 886-892, XP012102726, ISSN: 0734-2101, DOI: 10.1116/1.2749523 * the whole document *	1-15	

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
The Hague	18 November 2022	Malik, Jan

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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L : document cited for other reasons

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

REFERENCES CITED IN THE DESCRIPTION

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- US 63345549 **[0042]**