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(54) **ARTIFICIAL TURF SYSTEM**

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Description

Background

[0001] Interest in artificial turf in recent years has been explosive. Artificial turf (otherwise known as "pitch") is increasingly used to replace natural grass on playing surfaces, in particular on sports fields and playgrounds. Artificial turf also finds application in landscaping and leisure settings.

[0002] In "third generation artificial turf, or "3G turf," the artificial grass blades (the "pile") is supported by a thin base layer of sand, and by an infill of rubber crumb. The pile height ranges from 40 millimeters (mm) to 65 mm depending upon the primary sport to be played on the surface. Most 3G pitches consist of polyethylene (PE) yarns tufted to a primary backing. Typically, tuft lock is achieved by applying a polyurethane (PU) secondary backing coating or a styrene-butadiene-latex secondary backing coating. Infill is then spread between yarn fibers to stabilize the fiber vertical position, provide traction to players, and contribute to shock absorption of the system. In combination with suitable infill, a foamed PU shockpad layer is also installed under the system to optimize the shock absorption.

[0003] Artificial turf systems are used in contact sport pitches in order to improve player safety and to improve game consistency. A significant feature of artificial turf is its ability to absorb shocks. The shock absorption element of artificial turf includes the infill material and the shockpad. However, the use of these components presents a number of drawbacks.

[0004] Infill is disadvantageous because infill requires constant maintenance-uniform distribution of the infill granules is required to reduce risk of player injury. In addition, the shock absorption capability of the infill degrades over time, requiring replenishment of the infill and adding to the cost.

[0005] Use of crumb rubber and/or sand infill granules, alone or in combination with a PU shockpad makes incumbent artificial turf systems difficult to recycle leading incineration or disposal costs.

[0006] Document US 2015/167254 A1 discloses an artificial turf adapted for use in landscape and sports applications comprising a mechanically bounded layer of fibers formed as a non-woven matting made of one or more natural and/or synthetic fibers. A plurality of tufts of pile yarn is inserted through the mechanically bounded layer of fibers. A backing is applied at the backside of the mechanically bounded layer of fibers enhancing anchoring the tufts to the mechanically bounded layer of fibers.

[0007] Document US 2017/198442 A1 discloses a spring tension system for a floor tile that has spring loop with a base portion and a hoop portion.

[0008] Document WO 2013/060634 A1 discloses a shockpad comprising a three-dimensional entangled mat of extruded filaments made from a thermoplastic elastomeric polymer, especially a thermoplastic elastomeric polyester polymer or a thermoplastic elastomeric polyurethane polymer, provides improved shock absorption and energy restitution in artificial turf systems.

[0009] The art recognizes the need for alternative artificial turf systems with improved shock absorption capability alone or in combination with improved recyclability.

Summary

[0010] The present disclosure provides an artificial turf system. In an embodiment, the artificial turf system includes a primary backing layer and a shock absorption component. The primary backing layer has a plurality of artificial turf yarns projecting upwardly from the primary backing layer. The artificial turf system also includes a shock absorption component. The shock absorption component is composed of a sheet of three-dimensional random loop material (3DRLM). The sheet of 3DRLM is in contact with the primary backing layer. The shock absorption component includes (i) a cushioning layer and (ii) a shockpad. The 3DRLM in the cushioning layer has an apparent density that is greater than the apparent density of the 3DRLM in the shockpad.

[0011] An advantage of the present disclosure is an artificial turf system having a 3DRLM shock absorption component that is a single unitary component whereby the shockpad is integral to the cushioning layer. The integration of the shockpad and the cushioning into a single unitary shock absorption component eliminates the need for a secondary backing layer.

[0012] An advantage of the present disclosure is an artificial turf system with an integrated shockpad and cushioning layer that reduces the amount of infill material necessary for player safety.

[0013] An advantage of the present disclosure is an artificial turf system that is readily recyclable.

Description of the drawings

[0014]

FIG. 1 is a cutaway perspective view of an artificial turf system in accordance with an embodiment of the present

disclosure.

FIG. 1A is an enlarged view of area 1A of FIG. 1.

FIG. 2 is a perspective view of a shock absorption component in accordance with an embodiment of the present disclosure. Definitions

[0015] All references to the Periodic Table of the Elements herein shall refer to the Periodic Table of the Elements, published and copyrighted by CRC Press, Inc., 2003. Also, any references to a Group or Groups shall be to the Groups or Groups reflected in this Periodic Table of the Elements using the IUPAC system for numbering groups. Unless stated to the contrary, implicit from the context, or customary in the art, all components and percents are based on weight.

[0016] The numerical ranges disclosed herein include all values from, and including, the lower value and the upper value. For ranges containing explicit values (e.g., 1, or 2, or 3 to 5, or 6, or 7) any subrange between any two explicit values is included (e.g., 1 to 2; 2 to 6; 5 to 7; 3 to 7; 5 to 6; etc.).

[0017] Unless stated to the contrary, implicit from the context, or customary in the art, all components and percents are based on weight, and all test methods are current as of the filing date of this disclosure.

[0018] "Blend," "polymer blend" and like terms is a composition of two or more polymers. Such a blend may or may not be miscible. Such a blend may or may not be phase separated. Such a blend may or may not contain one or more domain configurations, as determined from transmission electron spectroscopy, light scattering, x-ray scattering, and any other method known in the art. Blends are not laminates, but one or more layers of a laminate can comprise a blend.

[0019] "Composition" and like terms is a mixture of two or more materials. Included in compositions are pre-reaction, reaction and post-reaction mixtures, the latter of which will include reaction products and by-products as well as unreacted components of the reaction mixture and decomposition products, if any, formed from the one or more components of the pre-reaction or reaction mixture.

[0020] The terms "comprising," "including," "having," and their derivatives, are not intended to exclude the presence of any additional component, step or procedure, whether or not the same is specifically disclosed. In order to avoid any doubt, all compositions claimed through use of the term "comprising" may include any additional additive, adjuvant, or compound, whether polymeric or otherwise, unless stated to the contrary. In contrast, the term, "consisting essentially of" excludes from the scope of any succeeding recitation any other component, step or procedure, excepting those that are not essential to operability. The term "consisting of" excludes any component, step or procedure not specifically delineated or listed.

[0021] An "ethylene-based polymer" is a polymer that contains more than 50 weight percent polymerized ethylene monomer (based on the total weight of polymerizable monomers) and, optionally, may contain at least one comonomer. Ethylene-based polymer includes ethylene homopolymer, and ethylene copolymer (meaning units derived from ethylene and one or more comonomers). The terms "ethylene-based polymer" and "polyethylene" may be used interchangeably. Nonlimiting examples of ethylene-based polymer (polyethylene) include low density polyethylene (LDPE) and linear polyethylene. Nonlimiting examples of linear polyethylene include linear low density polyethylene (LLDPE), ultra low density polyethylene (ULDPE), very low density polyethylene (VLDPE), multi-component ethylene-based copolymer (EPE), ethylene/ α -olefin multi-block copolymers (also known as olefin block copolymer (OBC)), single-site catalyzed linear low density polyethylene (m-LLDPE), substantially linear, or linear, plastomers/elastomers, and high density polyethylene (HDPE). Generally, polyethylene may be produced in gas-phase, fluidized bed reactors, liquid phase slurry process reactors, or liquid phase solution process reactors, using a heterogeneous catalyst system, such as Ziegler-Natta catalyst, a homogeneous catalyst system, comprising Group 4 transition metals and ligand structures such as metallocene, non-metallocene metal-centered, heteroaryl, heterovalent aryloxyether, phosphinimine, and others. Combinations of heterogeneous and/or homogeneous catalysts also may be used in either single reactor or dual reactor configurations.

[0022] "High density polyethylene" (or "HDPE") is an ethylene homopolymer or an ethylene/ α -olefin copolymer with at least one C_4 - C_{10} α -olefin comonomer, or C_4 - C_8 α -olefin comonomer and a density from greater than 0.94 g/cc, or 0.945 g/cc, or 0.95 g/cc, or 0.955 g/cc to 0.96 g/cc, or 0.97 g/cc, or 0.98 g/cc. The HDPE can be a monomodal copolymer or a multimodal copolymer. A "monomodal ethylene copolymer" is an ethylene/ C_4 - C_{10} α -olefin copolymer that has one distinct peak in a gel permeation chromatography (GPC) showing the molecular weight distribution. A "multimodal ethylene copolymer" is an ethylene/ C_4 - C_{10} α -olefin copolymer that has at least two distinct peaks in a GPC showing the molecular weight distribution. Multimodal includes copolymer having two peaks (bimodal) as well as copolymer having more than two peaks. Nonlimiting examples of HDPE include DOW™ High Density Polyethylene (HDPE) Resins (available from The Dow Chemical Company), ELITE™ Enhanced Polyethylene Resins (available from The Dow Chemical Company), CONTINUUM™ Bimodal Polyethylene Resins (available from The Dow Chemical Company), LUPOLEN™ (available from LyondellBasell), as well as HDPE products from Borealis, Ineos, and ExxonMobil.

[0023] An "interpolymer" is a polymer prepared by the polymerization of at least two different monomers. This generic term includes copolymers, usually employed to refer to polymers prepared from two different monomers, and polymers prepared from more than two different monomers, e.g., terpolymers, tetrapolymers, etc.

[0024] "Low density polyethylene" (or "LDPE") includes ethylene homopolymer, or ethylene/ α -olefin copolymer comprising at least one C₃-C₁₀ α -olefin, preferably C₃-C₄ α -olefin the LDPE having a density from 0.915 g/cc to 0.940 g/cc and containing a long chain branching with broad MWD. LDPE is typically produced by way of high pressure free radical polymerization (tubular reactor or autoclave with free radical initiator). Nonlimiting examples of LDPE include MarFlex™

(Chevron Phillips), LUPOLEN™ (LyondellBasell), as well as LDPE products from Borealis, Ineos, ExxonMobil, and others. **[0025]** "Linear low density polyethylene" (or "LLDPE") is a linear ethylene/ α -olefin copolymer containing heterogeneous short-chain branching distribution comprising units derived from ethylene and units derived from at least one C₃-C₁₀ α -olefin comonomer or at least one C₄-C₈ α -olefin comonomer, or at least one C₆-C₈ α -olefin comonomer. LLDPE is characterized by little, if any, long chain branching, in contrast to conventional LDPE. LLDPE has a density from 0.910 g/cc, or 0.915 g/cc, or 0.920 g/cc, or 0.925 g/cc to 0.930 g/cc, or 0.935 g/cc, or 0.940 g/cc. Nonlimiting examples of LLDPE include TUFLIN™ linear low density polyethylene resins (available from The Dow Chemical Company), DOWLEX™ polyethylene resins (available from the Dow Chemical Company), and MARLEX™ polyethylene (available from Chevron Phillips).

[0026] "Ultra low density polyethylene" (or "ULDPE") and "very low density polyethylene" (or "VLDPE") each is a linear ethylene/ α -olefin copolymer containing heterogeneous short-chain branching distribution comprising units derived from ethylene and units derived from at least one C₃-C₁₀ α -olefin comonomer, or at least one C₄-C₈ α -olefin comonomer, or at least one C₆-C₈ α -olefin comonomer. ULDPE and VLDPE each has a density from 0.885 g/cc, or 0.90 g/cc to 0.915 g/cc. Nonlimiting examples of ULDPE and VLDPE include ATTANE™ ultra low density polyethylene resins (available from The Dow Chemical Company) and FLEXOMER™ very low density polyethylene resins (available from The Dow Chemical Company).

[0027] "Multi-component ethylene-based copolymer" (or "EPE") comprises units derived from ethylene and units derived from at least one C₃-C₁₀ α -olefin comonomer, or at least one C₄-C₈ α -olefin comonomer, or at least one C₆-C₈ α -olefin comonomer, such as described in patent references USP 6,111,023; USP 5,677,383; and USP 6,984,695. EPE resins have a density from 0.905 g/cc, or 0.908 g/cc, or 0.912 g/cc, or 0.920 g/cc to 0.926 g/cc, or 0.929 g/cc, or 0.940 g/cc, or 0.962 g/cc. Nonlimiting examples of EPE resins include ELITE™ enhanced polyethylene (available from The Dow Chemical Company), ELITE AT™ advanced technology resins (available from The Dow Chemical Company), SURPASS™ Polyethylene (PE) Resins (available from Nova Chemicals), and SMART™ (available from SK Chemicals Co.).

[0028] "Single-site catalyzed linear low density polyethylenes" (or "m-LLDPE") are linear ethylene/ α -olefin copolymers containing homogeneous short-chain branching distribution comprising units derived from ethylene and units derived from at least one C₃-C₁₀ α -olefin comonomer, or at least one C₄-C₈ α -olefin comonomer, or at least one C₆-C₈ α -olefin comonomer. m-LLDPE has density from 0.913 g/cc, or 0.918 g/cc, or 0.920 g/cc to 0.925 g/cc, or 0.940 g/cc. Nonlimiting examples of m-LLDPE include EXCEED™ metallocene PE (available from ExxonMobil Chemical), LUFLEXEN™ m-LLDPE (available from LyondellBasell), and ELTEX™ PF m-LLDPE (available from Ineos Olefins & Polymers).

[0029] "Ethylene plastomers/elastomers" are substantially linear, or linear, ethylene/ α -olefin copolymers containing homogeneous short-chain branching distribution comprising units derived from ethylene and units derived from at least one C₃-C₁₀ α -olefin comonomer, or at least one C₄-C₈ α -olefin comonomer, or at least one C₆-C₈ α -olefin comonomer. Ethylene plastomers/elastomers have a density from 0.870 g/cc, or 0.880 g/cc, or 0.890 g/cc to 0.900 g/cc, or 0.902 g/cc, or 0.904 g/cc, or 0.909 g/cc, or 0.910 g/cc, or 0.917 g/cc. Nonlimiting examples of ethylene plastomers/ elastomers include AFFINITY™ plastomers and elastomers (available from The Dow Chemical Company), EXACT™ Plastomers (available from ExxonMobil Chemical), Tafmer™ (available from Mitsui), Nexlene™ (available from SK Chemicals Co.), and Lucene™ (available LG Chem Ltd.).

[0030] An "olefin-based polymer," as used herein, is a polymer that contains more than 50 weight percent polymerized olefin monomer (based on total amount of polymerizable monomers), and optionally, may contain at least one comonomer. Nonlimiting examples of olefin-based polymer include ethylene-based polymer and propylene-based polymer.

[0031] A "polymer" is a compound prepared by polymerizing monomers, whether of the same or a different type, that in polymerized form provide the multiple and/or repeating "units" or "mer units" that make up a polymer. The generic term polymer thus embraces the term homopolymer, usually employed to refer to polymers prepared from only one type of monomer, and the term copolymer, usually employed to refer to polymers prepared from at least two types of monomers. It also embraces all forms of copolymer, e.g., random, block, etc. The terms "ethylene/ α -olefin polymer" and "propylene/ α -olefin polymer" are indicative of copolymer as described above prepared from polymerizing ethylene or propylene respectively and one or more additional, polymerizable α -olefin monomer. It is noted that although a polymer is often referred to as being "made of" one or more specified monomers, "based on" a specified monomer or monomer type, "containing" a specified monomer content, or the like, in this context the term "monomer" is understood to be referring to the polymerized remnant of the specified monomer and not to the unpolymerized species. In general, polymers herein are referred to as being based on "units" that are the polymerized form of a corresponding monomer.

[0032] A "propylene-based polymer" is a polymer that contains more than 50 weight percent polymerized propylene monomer (based on the total amount of polymerizable monomers) and, optionally, may contain at least one comonomer.

Test methods

[0033] Apparent density. A sample material is cut into a square piece of 38 cm × 38 cm (15 in × 15 in) in size. The volume of this piece is calculated from the thickness measured at four points. The division of the weight by the volume gives the apparent density (an average of four measurements is taken) with values reported in grams per cubic centimeter, g/cc.

[0034] Ball rebound: A ball is released from 2 meters and the height of its rebound from the surface is calculated. Results are reported in meters (m).

[0035] Bending Stiffness. The bending stiffness is measured in accordance with DIN 53121 standard, with compression molded plaques of 550 μm thickness, using a Frank-PTI Bending Tester. The samples are prepared by compression molding of resin granules per ISO 293 standard. Conditions for compression molding are chosen per ISO 1872 - 2007 standard. The average cooling rate of the melt is 15°C/min. Bending stiffness is measured in 2-point bending configuration at room temperature with a span of 20 mm, a sample width of 15 mm, and a bending angle of 40°. Bending is applied at 6°/second (s) and the force readings are obtained from 6 to 600 s, after the bending is complete. Each material is evaluated four times with results reported in Newton millimeters ("Nmm").

[0036] ¹³C Nuclear Magnetic Resonance (NMR)

Sample Preparation

[0037] The samples are prepared by adding approximately 2.7 g of a 50/50 mixture of tetrachloroethane-d₂/orthodichlorobenzene that is 0.025M in chromium acetylacetonate (relaxation agent) to 0.21 g sample in a 10 mm NMR tube. The samples are dissolved and homogenized by heating the tube and its contents to 150°C.

Data Acquisition Parameters

[0038] The data is collected using a Bruker 400 MHz spectrometer equipped with a Bruker Dual DUL high-temperature CryoProbe. The data is acquired using 320 transients per data file, a 7.3 sec pulse repetition delay (6 sec delay+1.3 sec acq. time), 90 degree flip angles, and inverse gated decoupling with a sample temperature of 125°C. All measurements are made on non-spinning samples in locked mode. Samples are homogenized immediately prior to insertion into the heated (130°C) NMR Sample changer, and are allowed to thermally equilibrate in the probe for 15 minutes prior to data acquisition.

Crystallization Elution Fractionation (CEF) Method

[0039] Comonomer distribution analysis is performed with Crystallization Elution Fractionation (CEF) (PolymerChar in Spain) (B Monrabal et al, Macromol. Symp. 257, 71-79 (2007)). Ortho-dichlorobenzene (ODCB) with 600 ppm antioxidant butylated hydroxytoluene (BHT) is used as solvent. Sample preparation is done with autosampler at 160°C for 2 hours under shaking at 4 mg/ml (unless otherwise specified). The injection volume is 300 μm. The temperature profile of CEF is: crystallization at 3°C/min from 110°C to 30°C, the thermal equilibrium at 30°C for 5 minutes, elution at 3°C/min from 30°C to 140°C. The flow rate during crystallization is at 0.052 ml/min. The flow rate during elution is at 0.50 ml/min. The data is collected at one data point/second. CEF column is packed by the Dow Chemical Company with glass beads at 125 μm + 6% (MO-SCI Specialty Products) with 1/8 inch stainless tubing. Glass beads are acid washed by MO-SCI Specialty with the request from The Dow Chemical Company. Column volume is 2.06 ml. Column temperature calibration is performed by using a mixture of NIST Standard Reference Material Linear polyethylene 1475a (1.0 mg/ml) and Eicosane (2 mg/ml) in ODCB. Temperature is calibrated by adjusting elution heating rate so that NIST linear polyethylene 1475a has a peak temperature at 101.0°C, and Eicosane has a peak temperature of 30.0°C. The CEF column resolution is calculated with a mixture of NIST linear polyethylene 1475a (1.0 mg/ml) and hexacontane (Fluka, purum, >97.0, 1 mg/ml). A baseline separation of hexacontane and NIST polyethylene 1475a is achieved. The area of hexacontane (from 35.0 to 67.0°C) to the area of NIST 1475a from 67.0 to 110.0°C is 50 to 50, the amount of soluble fraction below 35.0°C is <1.8 wt%. The CEF column resolution is defined in the following equation:

$$\text{Resolution} = \frac{\text{Peak temperature of NIST 1475a} - \text{Peak Temperature of Hexacontane}}{\text{Half - height Width of NIST 1475a} + \text{Half - height Width of Hexacontane}}$$

where the column resolution is 6.0.

[0040] Density is measured in accordance with ASTM D 792 with values reported in grams per cubic centimeter, g/cc.

[0041] Differential Scanning Calorimetry (DSC). Differential Scanning Calorimetry (DSC) is used to measure the melting

and crystallization behavior of a polymer over a wide range of temperatures. For example, the TA Instruments Q1000 DSC, equipped with an RCS (refrigerated cooling system) and an autosampler is used to perform this analysis. During testing, a nitrogen purge gas flow of 50 ml/min is used. Each sample is melt pressed into a thin film at about 175°C; the melted sample is then air-cooled to room temperature (approx. 25°C). The film sample is formed by pressing a "0.1 to 0.2 gram" sample at 175°C at 1,500 psi, and 30 seconds, to form a "0.1 to 0.2 mil thick" film. A 3-10 mg, 6 mm diameter specimen is extracted from the cooled polymer, weighed, placed in a light aluminum pan (ca 50 mg), and crimped shut. Analysis is then performed to determine its thermal properties. The thermal behavior of the sample is determined by ramping the sample temperature up and down to create a heat flow versus temperature profile. First, the sample is rapidly heated to 180°C, and held isothermal for five minutes, in order to remove its thermal history. Next, the sample is cooled to -40°C, at a 10°C/minute cooling rate, and held isothermal at -40°C for five minutes. The sample is then heated to 150°C (this is the "second heat" ramp) at a 10°C/minute heating rate. The cooling and second heating curves are recorded. The cool curve is analyzed by setting baseline endpoints from the beginning of crystallization to -20°C. The heat curve is analyzed by setting baseline endpoints from -20°C to the end of melt. The values determined are peak melting temperature (T_m), peak crystallization temperature (T_c), onset crystallization temperature (T_c onset), heat of fusion (H_f) (in Joules per gram), the calculated % crystallinity for polyethylene samples using: % Crystallinity for PE = ((H_f)/(292 J/g)) × 100, and the calculated % crystallinity for polypropylene samples using: % Crystallinity for PP = ((H_f)/165 J/g) × 100. The heat of fusion (H_f) and the peak melting temperature are reported from the second heat curve. Peak crystallization temperature and onset crystallization temperature are determined from the cooling curve.

[0042] Elastic Recovery. Resin pellets are compression molded following ASTM D4703, Annex A1, Method C to a thickness of approximately 5-10 mil. Microtensile test specimens of geometry as detailed in ASTM D1708 are punched out from the molded sheet. The test specimens are conditioned for 40 hours prior to testing in accordance with Procedure A of Practice D618.

[0043] The samples are tested in a screw-driven or hydraulically-driven tensile tester using flat, rubber faced grips. The grip separation is set at 22 mm, equal to the gauge length of the microtensile specimens. The sample is extended to a strain of 100% at a rate of 100%/min and held for 30s. The crosshead is then returned to the original grip separation at the same rate and held for 60s. The sample is then strained to 100% at the same 100%/min strain rate.

[0044] Elastic recovery may be calculated as follows:

$$\text{Elastic Recovery} = \frac{(\text{Initial Applied Strain} - \text{Permanent Set})}{\text{Initial Applied Strain}} \times 100\%$$

[0045] Energy restitution: A mass with a spring attached falls onto the turf. The energy restitution is given by the comparison of energy of the falling mass before and after impact on the test specimen. Results are reported in percentage (%).

[0046] Indentation Load Deflection (ILD) is a measure of firmness for a material. In general, the higher the ILD value, the more firm the material; the lower the ILD value, the less firm the material. ILD measurement is performed in the sample thickness direction. The test protocol is in accordance with ASTM standard D 3574.

[0047] For ILD testing, a square bottom plate and a round top plate are aligned with their centers coincident. The bottom plate is 13 × 13 in, and the top plate's diameter is 8 inches. Each test specimen is 12 inches × 12 inches.

[0048] The ILD test is performed on an Instron material testing system in displacement-control mode. The bottom plate stays stationary, and the top plate is actuated to move up or down as an indenter. The indenter is lowered towards the bottom plate until the load cell just starts to register some compression, which means that there is physical contact between the two plates. The indenter position is recorded as the origin d₀. With the test specimen sitting on the bottom plate, the indenter is lowered again until the load cell registers about 4.5 N of compression force. The indenter position is recorded as d. The specimen thickness is the difference between the two readings (d - d₀).

[0049] The test procedure consists of two steps: pre-flexing and actual ILD measurements. In the pre-flexing step, the indenter is driven into the specimen between 75% and 80% of the thickness for two cycles (based on the initial thickness measurement obtained with the protocol specified in paragraph above. The loading/unloading rate is 250 mm/min. Then the specimen is left to recover for 6 minutes before the second step starts. The objective of pre-flexing is to eliminate structural hysteresis for an accurate thickness measurement. In the second step, the specimen thickness is measured again. The indenter is programmed to compress the specimen with 25% of the thickness (based on the second time thickness measurement). The indenter holds its position for 60 seconds to allow specimen relaxation until the force reading is recorded as 25% ILD. The indenter continues to move downwards for another 40% thickness to reach 65% of the specimen thickness. The position is held for 60 seconds before the 65% ILD is recorded. The loading/unloading rate is 50 mm/min.

[0050] Each specimen is tested three times. Between tests, specimens rested for at least 40 minutes as a precaution to allow specimen recovery. ILD results are reported in Newtons (N).

[0051] Melt flow rate (MFR) is measured in accordance with ASTM D 1238, Condition 280°C/2.16 kg (g/10 minutes).

[0052] Melt index (MI) is measured in accordance with ASTM D 1238, Condition 190°C/2.16 kg (g/10 minutes).

[0053] Molecular weight distribution (Mw/Mn) is measured using Gel Permeation Chromatography (GPC). In particular, conventional GPC measurements are used to determine the weight-average (Mw) and number-average (Mn) molecular weight of the polymer and to determine the Mw/Mn. The gel permeation chromatographic system consists of either a Polymer Laboratories Model PL-210 or a Polymer Laboratories Model PL-220 instrument. The column and carousel compartments are operated at 140°C. Three Polymer Laboratories 10-micron Mixed-B columns are used. The solvent is 1,2,4 trichlorobenzene. The samples are prepared at a concentration of 0.1 grams of polymer in 50 milliliters of solvent containing 200 ppm of butylated hydroxytoluene (BHT). Samples are prepared by agitating lightly for 2 hours at 160°C. The injection volume used is 100 microliters and the flow rate is 1.0 ml/minute.

[0054] Calibration of the GPC column set is performed with 21 narrow molecular weight distribution polystyrene standards with molecular weights ranging from 580 to 8,400,000, arranged in 6 "cocktail" mixtures with at least a decade of separation between individual molecular weights. The standards are purchased from Polymer Laboratories (Shropshire, UK). The polystyrene standards are prepared at 0.025 grams in 50 milliliters of solvent for molecular weights equal to or greater than 1,000,000, and 0.05 grams in 50 milliliters of solvent for molecular weights less than 1,000,000. The polystyrene standards are dissolved at 80°C with gentle agitation for 30 minutes. The narrow standards mixtures are run first and in order of decreasing highest molecular weight component to minimize degradation. The polystyrene standard peak molecular weights are converted to polyethylene molecular weights using the following equation (as described in Williams and Ward, J. Polym. Sci., Polym. Let., 6, 621 (1968)):

$$M_{\text{polypropylene}} = 0.645(M_{\text{polystyrene}}).$$

[0055] Polypropylene equivalent molecular weight calculations are performed using Viscotek TriSEC software Version 3.0.

[0056] "Porosity" is the percent of open volume for the 3DRLM. The mass and the dimensions of a 3DRLM sample are measured and the bulk density is calculated. The percent of open volume for the 3DRLM sample is the ratio of the volume of a 3DRLM sample to the volume of a solid polymer of the same mass, using the polymer solid density. Results for porosity are reported in percent (%).

[0057] Shock Absorption: A mass with a spring attached falls onto the artificial turf system. The shock absorption is calculated by comparing the maximum force on the turf with the reference for impact on concrete. Results are reported in percentage (%).

[0058] Tensile Strength is measured using a hybrid of ASTM D638 (Rigid Plastics) and ASTM D882 (Films). The samples are sheets of 3DRLM shockpad SAC1 with dimensions 203mm by 31.7 mm (8 inches long and 1.25 inches wide). The gauge length between the test grips is set at 127 mm (5 inches) and the pull speed used is 50 mm/min.

[0059] Vertical deformation: A mass with a spring attached falls onto the turf. The vertical deformation is calculated by the displacement of the falling mass into the test specimen after its impact on it. Results are reported in millimeters (mm).

Detailed description

[0060] The present disclosure provides an artificial turf system. In an embodiment, the artificial turf system includes a primary backing layer with a plurality of artificial turf yarns projecting upwardly from the primary backing layer. The artificial turf system also includes a shock absorption component. The shock absorption component is composed of a sheet of three-dimensional random loop material (3DRLM). The 3DRLM sheet is in contact with the primary backing layer. The shock absorption component includes (i) a cushioning layer and (ii) a shockpad. The 3DRLM in the cushioning layer has an apparent density that is greater than the apparent density of the 3DRLM in the shockpad. An exposed surface of the cushioning layer contacts a bottom surface of the primary backing layer.

[0061] FIG. 1 shows an embodiment of the present artificial turf system 10 having a primary backing layer 12, with an plurality of artificial turf yarns 14 projecting upwardly therefrom. The term "artificial turf," as used herein, is a carpet-like cover having substantially upright, or upright, polymer strands of the artificial turf yarn 14 projecting upwardly from a substrate which is the primary backing layer 12. The artificial turf system 10 also includes a shock absorption component 20. The shock absorption component 20 contacts the bottom side of the primary backing layer 12. The shock absorption component 20 is composed of a three-dimensional random loop material 30. The shock absorption component 20 includes (i) a cushioning layer 40 and (ii) a shockpad 50. The shock absorption component 20 is an integral structure as will be described below.

[0062] The "primary backing layer" is one or more sheets onto which the artificial turf yarn is sewn or woven such that the artificial turf yarn extends outwardly from the top side of the primary backing layer. The primary backing layer may be a polymeric sheet of woven fabric or a polymeric sheet of non-woven fabric. The primary backing layer provides

dimensional stability for the artificial turf system.

[0063] Nonlimiting examples of suitable polymeric material for the primary backing layer include styrene-butadiene rubber (SBR) and propylene-based polymer. In an embodiment, the primary backing layer is composed of an olefin-based polymer, such as a propylene-based polymer. In a further embodiment, the primary backing layer is composed of propylene homopolymer.

[0064] The present artificial turf system 10 includes a plurality of artificial turf yarns 14 projecting upwardly from the primary backing layer 12. The term "artificial turf yarn" or hereafter "yarn," as used herein, includes fibrillated tape yarn, co-extruded tape yarn, monotape yarn and monofilament yarn. A "fibrillated tape" or "fibrillated tape yarn," is a cast extruded film cut into tape (typically about 1 cm width), the film stretched and long slits cut (fibrillated) into the tape giving the tape the dimensions of grass blades. A "monofilament yarn" is extruded into individual yarn or strands with a desired cross-sectional shape and thickness followed by yarn orientation and relaxation in hot ovens. The artificial turf yarn forms the polymer strands for the artificial turf. Artificial turf requires resilience (springback), toughness, flexibility, extensibility and durability. Consequently, artificial turf yarn excludes yarn for fabrics (i.e., woven and/or knit fabrics).

[0065] The yarn 14 is composed of a polymeric material. Nonlimiting examples of suitable polymeric material for the yarn include olefin-based polymer (such as propylene-based polymer and/or ethylene-based polymer), polyester, nylon, and combinations thereof. In an embodiment, the yarn 14 is composed of an ethylene-based polymer.

[0066] The artificial turf system 10 includes the shock absorption component 20. The shock absorption component 20 is composed of a sheet 22 of three-dimensional random loop material 30. As shown in FIG. 2, a "three-dimensional random loop material" (or "3DRLM") is a mass or a structure of a multitude of loops 32 formed by allowing continuous fibers 34, to wind, permitting respective loops to come in contact with one another in a molten state and to be heat-bonded, or otherwise melt-bonded, at most of the contact points 36. Even when a great stress to cause significant deformation is given, the 3DRLM 30 absorbs the stress with the entire net structure composed of three-dimensional random loops melt-integrated, by deforming itself; and once the stress is lifted, elastic resilience of the polymer manifests itself to allow recovery to the original shape of the structure. When a net structure composed of continuous fibers made from a known non-elastic polymer is used as a cushioning material, plastic deformation is developed and the recovery cannot be achieved, thus resulting in poor heat-resisting durability. When the fibers are not melt-bonded at contact points, the shape cannot be retained and the structure does not integrally change its shape, with the result that a fatigue phenomenon occurs due to the concentration of stress, thus unbeneficially degrading durability and deformation resistance. In certain embodiments, melt-bonding is the state where all contact points are melt-bonded.

[0067] A nonlimiting method for producing 3DRLM 30 includes the steps of (a) heating a molten olefin-based polymer, at a temperature 10°C-140°C higher than the melting point of the polymer in a typical melt-extruder; (b) discharging the molten interpolymer to the downward direction from a nozzle with plural orifices to form loops by allowing the fibers to fall naturally (due to gravity). The polymer may be used in combination with a thermoplastic elastomer, thermoplastic non-elastic polymer or a combination thereof. The distance between the nozzle surface and take-off conveyors installed on a cooling unit for solidifying the fibers, melt viscosity of the polymer, diameter of orifice and the amount to be discharged are the elements which decide loop diameter and fineness of the fibers. Loops are formed by holding and allowing the delivered molten fibers to reside between a pair of take-off conveyors (belts, or rollers) set on a cooling unit (the distance therebetween being adjustable), bringing the loops thus formed into contact with one another by adjusting the distance between the orifices to this end such that the loops in contact are heat-bonded, or otherwise melt-bonded, as they form a three-dimensional random loop structure. Then, the continuous fibers, wherein contact points have been heat-bonded as the loops form a three-dimensional random loop structure, are continuously taken into a cooling unit for solidification to give a net structure. Thereafter, the structure is cut into a desired length and shape. The method is characterized in that the olefin-based polymer is melted and heated at a temperature 10°C-140°C higher than the melting point of the interpolymer and delivered to the downward direction in a molten state from a nozzle having plural orifices. When the polymer is discharged at a temperature less than 10°C higher than the melting point, the fiber delivered becomes cool and less fluidic to result in insufficient heat-bonding of the contact points of fibers.

[0068] Properties, such as, the loop diameter and fineness of the fibers constituting the cushioning net structure provided herein depend on the distance between the nozzle surface and the take-off conveyor installed on a cooling unit for solidifying the interpolymer, melt viscosity of the interpolymer, diameter of orifice and the amount of the interpolymer to be delivered therefrom. For example, a decreased amount of the interpolymer to be delivered and a lower melt viscosity upon delivery result in smaller fineness of the fibers and smaller average loop diameter of the random loop. On the contrary, a shortened distance between the nozzle surface and the take-off conveyor installed on the cooling unit for solidifying the interpolymer results in a slightly greater fineness of the fiber and a greater average loop diameter of the random loop. These conditions in combination afford the desirable fineness of the continuous fibers of from 100 denier to 100000 denier and an average diameter of the random loop of not more than 100 mm, or from 1 millimeter (mm), or 2 mm, or 10 mm to 25 mm, or 50 mm. By adjusting the distance to the aforementioned conveyor, the thickness of the structure can be controlled while the heat-bonded net structure is in a molten state and a structure having a desirable thickness and flat surface formed by the conveyors can be obtained. Too great a conveyor speed results in failure to

heat-bond the contact points, since cooling proceeds before the heat-bonding. On the other hand, too slow a speed can cause higher density resulting from excessively long dwelling of the molten material. In some embodiments the distance to the conveyor and the conveyor speed should be selected such that the desired apparent density of 0.005-0.1 g/cc or 0.01-0.05 g/cc can be achieved.

[0069] In an embodiment, the 3DRLM 30 has, one, some, or all of the properties (i) - (iii) below:

- (i) a fiber diameter from 0.1 mm, or 0.5 mm, or 0.7 mm, or 1.0 mm or 1.5 mm to 2.0 mm to 2.5 mm, or 3.0 mm; and/or
- (ii) a thickness (machine direction) from 0.5 cm, or 1.0 cm, 2.0 cm, or 3.0, cm, or 4.0 cm, or 5.0 cm, or 10 cm, or 20 cm, to 50 cm, or 75 cm, or 100 cm, or more. It is understood that the thickness of the 3DRLM 30 will vary based on target application for the artificial turf system.

[0070] The 3DRLM 30 is formed into a three dimensional geometric shape to form a sheet (i.e., a prism). The 3DRLM 30 is an elastic material which can be compressed and stretched and return to its original geometric shape. An "elastic material," as used herein, is a rubber-like material that can be compressed and/or stretched and which expands/retracts very rapidly to approximately its original shape/length when the force exerting the compression and/or the stretching is released. The three dimensional random loop material 30 has a "neutral state" when no compressive force and no stretch force is imparted upon the 3DRLM 30. The three dimensional random loop material 30 has "a compressed state" when a compressive force is imparted upon the 3DRLM 30. The three dimensional random loop material 30 has "a stretched state" when a stretching force is imparted upon the 3DRLM 30.

[0071] The three dimensional random loop material 30 is composed of one or more olefin-based polymers. The olefin-based polymer can be one or more ethylene-based polymers, one or more propylene-based polymers, and blends thereof.

[0072] In an embodiment, the ethylene-based polymer is an ethylene/ α -olefin copolymer. Ethylene/ α -olefin copolymer may be a random ethylene/ α -olefin polymer or an ethylene/ α -olefin multi-block polymer. The α -olefin is a C_3 - C_{20} α -olefin, or a C_4 - C_{12} α -olefin, or a C_4 - C_8 α -olefin. Nonlimiting examples of suitable α -olefin comonomer include propylene, butene, methyl-1-pentene, hexene, octene, decene, dodecene, tetradecene, hexadecene, octadecene, cyclohexyl-1-propene (allyl cyclohexane), vinyl cyclohexane, and combinations thereof.

[0073] In an embodiment, the ethylene-based polymer is a homogeneously branched random ethylene/ α -olefin copolymer.

[0074] "Random copolymer" is a copolymer wherein the at least two different monomers are arranged in a non-uniform order. The term "random copolymer" specifically excludes block copolymers. The term "homogeneous ethylene polymer" as used to describe ethylene polymers is used in the conventional sense in accordance with the original disclosure by Elston in U.S. Pat. No. 3,645,992, to refer to an ethylene polymer in which the comonomer is randomly distributed within a given polymer molecule and wherein substantially all of the polymer molecules have substantially the same ethylene to comonomer molar ratio. As defined herein, both substantially linear ethylene polymers and homogeneously branched linear ethylene are homogeneous ethylene polymers.

[0075] The homogeneously branched random ethylene/ α -olefin copolymer may be a random homogeneously branched linear ethylene/ α -olefin copolymer or a random homogeneously branched substantially linear ethylene/ α -olefin copolymer. The term "substantially linear ethylene/ α -olefin copolymer" means that the polymer backbone is substituted with from 0.01 long chain branches/1000 carbons to 3 long chain branches/1000 carbons, or from 0.01 long chain branches/1000 carbons to 1 long chain branches/1000 carbons, or from 0.05 long chain branches/1000 carbons to 1 long chain branches/1000 carbons. In contrast, the term "linear ethylene/ α -olefin copolymer" means that the polymer backbone has no long chain branching.

[0076] The homogeneously branched random ethylene/ α -olefin copolymers may have the same ethylene/ α -olefin comonomer ratio within all copolymer molecules. The homogeneity of the copolymers may be described by the SCBDI (Short Chain Branch Distribution Index) or CDBI (Composition Distribution Branch Index) and is defined as the weight percent of the polymer molecules having a comonomer content within 50 percent of the median total molar comonomer content. The CDBI of a polymer is readily calculated from data obtained from techniques known in the art, such as, for example, temperature rising elution fractionation (abbreviated herein as "TREF") as described in U.S. Pat. No. 4,798,081 (Hazlitt et al.), or in U.S. Pat. No. 5,089,321 (Chum et al.) The SCBDI or CDBI for the homogeneously branched random ethylene/ α -olefin copolymers is preferably greater than about 30 percent, or greater than about 50 percent.

[0077] The homogeneously branched random ethylene/ α -olefin copolymer may include at least one ethylene comonomer and at least one C_3 - C_{20} α -olefin, or at least one C_4 - C_{12} α -olefin comonomer. For example and not by way of limitation, the C_3 - C_{20} α -olefins may include but are not limited to propylene, isobutylene, 1-butene, 1-hexene, 4-methyl-1-pentene, 1-heptene, 1-octene, 1-nonene, and 1-decene, or, in some embodiments, 1-butene, 1-hexene, 4-methyl-1-pentene and 1-octene.

[0078] In an embodiment, the homogeneously branched random ethylene/ α -olefin copolymer consists of ethylene and a C_4 - C_8 α -olefin comonomer and has one, some, or all of the following properties (i) - (iii) below:

- (i) a melt index (I_2) from 1 g/10 min, or 5 g/10 min, or 10 g/10 min, or 20 g/10 min to 30 g/10 min, or 40 g/10 min, or 50 g/10 min, and/or
- (ii) a density from 0.75 g/cc, or 0.880 g/cc, or 0.890 g/cc to 0.90 g/cc, or 0.91 g/cc, or 0.920 g/cc, or 0.925 g/cc; and/or
- (iii) a molecular weight distribution (Mw/Mn) from 2.0, or 2.5, or 3.0 to 3.5, or 4.0.

[0079] In an embodiment, the ethylene-based polymer is a heterogeneously branched random ethylene/ α -olefin copolymer.

[0080] The heterogeneously branched random ethylene/ α -olefin copolymer differs from the homogeneously branched random ethylene/ α -olefin copolymer primarily in the branching distribution. For example, heterogeneously branched random ethylene/ α -olefin copolymers have a distribution of branching, including a highly branched portion (similar to a very low density polyethylene), a medium branched portion (similar to a medium branched polyethylene) and an essentially linear portion (similar to linear homopolymer polyethylene).

[0081] Like the homogeneously branched random ethylene/ α -olefin copolymer, the heterogeneously branched random ethylene/ α -olefin copolymer may include at least one ethylene comonomer and at least one C_3 - C_{20} α -olefin comonomer, or at least one C_4 - C_{12} α -olefin comonomer. For example and not by way of limitation, the C_3 - C_{20} α -olefins may include but are not limited to, propylene, isobutylene, 1-butene, 1-hexene, 4-methyl-1-pentene, 1-heptene, 1-octene, 1-nonene, and 1-decene, or, in some embodiments, 1-butene, 1-hexene, 4-methyl-1-pentene and 1-octene. In one embodiment, the heterogeneously branched ethylene/ α -olefin copolymer may comprise greater than about 50% by wt ethylene copolymer, or greater than about 60% by wt., or greater than about 70% by wt. Similarly, the heterogeneously branched ethylene/ α -olefin copolymer may comprise less than about 50% by wt α -olefin monomer, or less than about 40% by wt., or less than about 30% by wt.

[0082] In an embodiment, the heterogeneously branched random ethylene/ α -olefin copolymer consists of ethylene and a C_4 - C_8 α -olefin comonomer and has one, some, or all of the following properties (i) - (iii) below:

- (i) a density from 0.900 g/cc, or 0.0910 g/cc, or 0.920 g/cc to 0.930 g/cc, or 0.094 g/cc;
- (ii) a melt index (I_2) from 1 g/10 min, or 5 g/10 min, or 10 g/10 min, or 20 g/10 min to 30 g/10 min, or 40 g/10 min, or 50 g/10 min; and/or
- (iii) an Mw/Mn from 3.0, or 3.5 to 4.0, or 4.5.

[0083] In an embodiment, the 3DRLM 30 is composed of a blend of a homogeneously branched random ethylene/ α -olefin copolymer and a heterogeneously branched ethylene/ α -olefin copolymer, the blend having one, some, or all of the properties (i) - (v) below:

- (i) a Mw/Mn from 2.5, or 3.0 to 3.5, or 4.0, or 4.5;
- (ii) a melt index (I_2) from 3.0 g/10 min, or 4.0 g/10 min, or 5.0 g/10 min, or 10 g/10 min to 15 g/10 min, or 20 g/10 min, or 25 g/10 min;
- (iii) a density from 0.895 g/cc, or 0.900 g/cc, or 0.910 g/cc, or 0.915 g/cc to 0.920 g/cc, or 0.925 g/cc; and/or
- (iv) an I_{10}/I_2 ratio from 5 g/10 min, or 7 g/10 min to 10 g/10 min, or 15 g/10 min; and/or
- (v) a percent crystallinity from 25%, or 30%, or 35%, or 40% to 45%, or 50%, or 55%.

[0084] According to Crystallization Elution Fractionation (CEF), the ethylene/ α -olefin copolymer blend may have a weight fraction in a temperature zone from 90°C to 115°C or about 5% to about 15% by wt., or about 6% to about 12%, or about 8% to about 12%, or greater than about 8%, or greater than about 9%. Additionally, as detailed below, the copolymer blend may have a Comonomer Distribution Constant (CDC) of at least about 100, or at least about 110.

[0085] The present ethylene/ α -olefin copolymer blend may have at least two, or three melting peaks when measured using Differential Scanning Calorimetry (DSC) below a temperature of 130°C. In one or more embodiments, the ethylene/ α -olefin copolymer blend may include a highest temperature melting peak of at least 115°C, or at least 120°C, or from about 120°C to about 125°C, or from about 122 to about 124°C. Without being bound by theory, the heterogeneously branched ethylene/ α -olefin copolymer is characterized by two melting peaks, and the homogeneously branched ethylene/ α -olefin copolymer is characterized by one melting peak, thus making up the three melting peaks.

[0086] Additionally, the ethylene/ α -olefin copolymer blend may comprise from about 10 to about 90% by weight, or about 30 to about 70% by weight, or about 40 to about 60% by weight of the homogeneously branched ethylene/ α -olefin copolymer. Similarly, the ethylene/ α -olefin copolymer blend may comprise from about 10 to about 90% by weight, about 30 to about 70% by weight, or about 40 to about 60% by weight of the heterogeneously branched ethylene/ α -olefin copolymer. In a specific embodiment, the ethylene/ α -olefin copolymer blend may comprise from about 50% to about 60% by weight of the homogeneously branched ethylene/ α -olefin copolymer, and 40% to about 50% of the heterogeneously branched ethylene/ α -olefin copolymer.

[0087] Moreover, the strength of the ethylene/ α -olefin copolymer blend may be characterized by one or more of the

following metrics. One such metric is elastic recovery. Here, the ethylene/ α -olefin copolymer blend has an elastic recovery, Re, in percent at 100 percent strain at 1 cycle of between 50-80%. Additional details regarding elastic recovery are provided in US Patent 7,803,728,

[0088] The ethylene/ α -olefin copolymer blend may also be characterized by its storage modulus. In some embodiments, the ethylene/ α -olefin copolymer blend may have a ratio of storage modulus at 25° C, G' (25°C) to storage modulus at 100°C, G' (100°C) of about 20 to about 60, or from about 20 to about 50, or about 30 to about 50, or about 30 to about 40.

[0089] Moreover, the ethylene/ α -olefin copolymer blend may also be characterized by a bending stiffness of at least about 1.15 Nmm at 6 s, or at least about 1.20 Nmm at 6 s, or at least about 1.25 Nmm at 6 s, or at least about 1.35 Nmm at 6 s. Without being bound by theory, it is believed that these stiffness values demonstrate how the ethylene/ α -olefin copolymer blend will provide cushioning support when incorporated into 3DRLM fibers bonded to form a cushioning net structure.

[0090] In an embodiment, the ethylene-based polymer is an ethylene/ α -olefin interpolymer composition having one, some, or all of the following properties (i)-(v) below:

- (i) a highest DSC temperature melting peak from 90.0°C to 115.0°C; and/or
- (ii) a zero shear viscosity ratio (ZSVR) from 1.40 to 2.10; and/or
- (iii) a density in the range of from 0.860 to 0.925 g/cc; and/or
- (iv) a melt index (I₂) from 1 g/10 min to 25 g/10 min; and/or
- (v) a molecular weight distribution (Mw/Mn) in the range of from 2.0 to 4.5.

[0091] In an embodiment, the 3DRLM 30 is composed of an ethylene/C₄-C₈ α -olefin copolymer that is an elastomer. An "elastomer," as used herein, refers to a rubber-like polymer that can be stretched to at least twice its original length and which retracts very rapidly to approximately its original length when the force exerting the stretching is released. An elastomer has an elastic modulus of about 10,000 psi (68.95 MPa) or less and an elongation usually greater than 200% in the uncrosslinked state at room temperature using the method of ASTM D638 - 72. In an embodiment, the 3DRLM 30 is composed of an "ethylene-based elastomer" which is an elastomer composed of least 50 wt% units derived from ethylene.

[0092] In an embodiment, the 3DRLM 30 is composed of an ethylene/C₄-C₈ α -olefin copolymer with a Comonomer Distribution Constant (CDC) in the range of from greater than 45 to less than 400, the ethylene/C₄-C₈ α -olefin copolymer having less than 120 total unsaturation unit/1,000,000C (hereafter referred to as "CDC45-ethylene copolymer"). Non-limiting examples of suitable CDC45-ethylene copolymer are found in US Patent Nos. 8372931 and 8829115,

[0093] In an embodiment, the CDC45-ethylene copolymer has one, some, or all of the following properties (i) - (iv) below:

- (i) a density from 0.86 g/cc, or 0.87 g/cc to 0.88 g/cc, or 0.89 g/cc; and/or
- (ii) a zero shear viscosity ratio (ZSVR) of at least 2; and/or
- (iii) less than 20 vinylidene unsaturation unit/1,000,000C; and/or
- (iv) a bimodal molecular weight distribution.

[0094] FIG. 2 shows the shock absorption component 20 includes the cushioning layer 40 and the shockpad 50. The cushioning layer 40 and the shockpad 50 each is composed of the 3DRLM 30.

[0095] As best seen in FIG. 1A and FIG. 2, the shock absorption component 20 is a single integral structure whereby the sub-components, cushioning layer 40 and shockpad 50, are essentially inseparable, or are inseparable, and constitute a single, unitary component—namely, the shock absorption component 20. The cushioning layer 40 and the shockpad 50 are formed simultaneously, in a single extrusion process, such that many (10's, or 100's, or 1000's) of 3DRLM fibers extend from the cushioning layer 40 and into the shockpad 50 and vice versa. In other words, the shock absorption component 20 is an integral structure whereby no intervening layer, and/or no intervening structure, and/or no intervening composition is present between the cushioning layer 40 and the shockpad 50.

[0096] The 3DRLM 30 of the shock absorption component 20 is composed of a plurality of multiple loops. The multiple loops are formed by a plurality of continuous fibers composed of polymeric material as previously disclosed. At least 2, or 3 or 4, or 5, or 6, or 7, or 8, or 9, or 10, or more continuous fibers 34 extend from the shockpad 50 to the cushioning layer 40 and vice versa. In an embodiment, hundreds, or thousands, of continuous fibers extend across the cushioning layer 40 and into the shockpad 50 and vice versa.

[0097] In an embodiment, the shock absorption component 20 includes cushioning layer 40, shockpad 50, and a second cushioning layer (not shown) integral with the shockpad 50. The 3DRLM in the second cushioning layer has an apparent density that is greater than the apparent density of the 3DRLM in the shockpad 50. The cushioning layer 40 and the second cushioning layer sandwich the shockpad 50. The second cushioning layer is located on the side opposite the cushioning layer 40. In other words, the cushioning layer 40 and the second cushioning layer are substantially parallel to, or parallel to, each other. The second cushioning layer is similar to the cushioning layer 40 in that that second

cushioning layer is composed of the same continuous fibers as the continuous fibers in the shockpad 50 and/or is composed of the same continuous fibers in the cushioning layer 40. The apparent density of the second cushioning layer can be the same as, or different than, the apparent density of the cushioning layer 40. The thickness of the second cushioning layer can be the same as, or different than, the thickness of the cushioning layer 40.

[0098] In an embodiment, the shockpad has a thickness, measured in millimeters (mm) that is from 2 times, or 3 times, or 10 times, or 15 times to 50 times, or 100 times, or 200 times, or 300 times greater than the thickness of the cushioning layer. In a further embodiment, the shockpad has a thickness from 3 times, or 5 times, or 8 times to 10 times, or 12 times, or 15 times greater than the thickness of the cushioning layer.

[0099] The 3DRLM in the cushioning layer 40 has an apparent density that is greater than the apparent density of the 3DRLM in the shockpad 50. FIG. 1A and FIG. 2 show the continuous fibers 34 in the cushioning layer 40 are more densely packed compared to the loosely packed continuous fibers 34 in the shockpad 50. This difference in fiber packing results in the cushioning layer 40 having an apparent density that is greater than the apparent density of the shockpad 50.

[0100] In an embodiment, the apparent density of the cushioning layer 40 is from 2 times, or 3 times, or 10 times, or 15 times to 50 times, or 100 times, or 200 times, or 300 times, or 400 times greater than the apparent density of the shockpad 50. In a further embodiment, the apparent density of the cushioning layer 40 is from 2 times, or 3 times, or 5 times or 8 times to 10 times, or 15 times, or 20 times greater than the apparent density of the shockpad 50.

[0101] In an embodiment, the shockpad 50 has an apparent density from 0.010 g/cc, or 0.016 g/cc, or 0.020 g/cc, or 0.050 g/cc, or 0.070 g/cc, or 0.100 g/cc, or 0.150 g/cc to 0.200 g/cc, or 0.250 g/cc, or 0.300 g/cc, or 0.330 g/cc, or 0.400 g/cc.

[0102] In an embodiment, the cushioning layer 40 has an apparent density from 0.030 g/cc, or 0.032 g/cc, or 0.050 g/cc, or 0.070 g/cc, or 0.100 g/cc, or 0.159 g/cc to 0.200 g/cc, or 0.250 g/cc, or 0.300 g/cc, or 0.400, or 0.500 g/cc, or 0.600 g/cc, or 0.700 g/cc, or 0.800 g/cc, or 0.900 g/cc, or 0.960 g/cc, or 1.000 g/cc.

[0103] In an embodiment, the shockpad 50 has an apparent density from 0.010 g/cc, or 0.016 g/cc, or 0.020 g/cc, or 0.050 g/cc, or 0.070 g/cc, or 0.100 g/cc, or 0.150 g/cc to 0.200 g/cc, or 0.250 g/cc, or 0.300 g/cc, or 0.330 g/cc, or 0.400 g/cc and the cushioning layer 40 has an apparent density from 0.030 g/cc, or 0.032 g/cc, or 0.050 g/cc, or 0.070 g/cc, or 0.100 g/cc, or 0.159 g/cc to 0.200 g/cc, or 0.250 g/cc, or 0.300 g/cc, or 0.400, or 0.500 g/cc, or 0.600 g/cc, or 0.700 g/cc, or 0.800 g/cc, or 0.900 g/cc, or 0.960 g/cc, or 1.000 g/cc with the proviso that the apparent density of the 3DRLM in the cushioning layer 40 is greater than the apparent density of the 3DRLM in the shockpad 50.

[0104] The shock absorption component 20 contacts the primary backing layer 12. More specifically, the exposed surface of the cushioning layer 40 contacts the bottom surface of the primary backing layer 12. The contact between the cushioning layer 40 and the primary backing layer 12 may be by way of (i) direct contact or (ii) indirect contact.

[0105] In an embodiment, the cushioning layer 40 directly contacts the bottom surface of the primary backing layer 12. The term "direct contact," as used herein, is the spatial relationship whereby the cushioning layer 40 touches the bottom of the primary backing layer 12 such that no intervening layer, and/or no intervening structure, and/or no intervening composition is present between the cushioning layer 40 and the primary backing layer 12.

[0106] In an embodiment, the cushioning layer 40 indirectly contacts the bottom surface of the primary backing layer 12. The term "indirect contact," as used herein, is the spatial relationship whereby an intervening layer, and/or an intervening structure, and/or an intervening composition is present between the cushioning layer 40 and the primary backing layer 12. The intervening layer/structure/composition may or may not be coextensive with the exposed surface of the cushioning layer 40. In a further embodiment, the cushioning layer 40 indirectly contacts the bottom surface of the primary backing layer 12 whereby an adhesive layer attaches, or otherwise bonds, the exposed surface of the cushioning layer 40 to the bottom surface of the primary backing layer 12.

[0107] In an embodiment, the artificial turf system 10 and/or the shock absorption component 20 is void of foam.

[0108] In an embodiment, the shock absorption component 20 is void of foam.

[0109] In an embodiment, the artificial turf system 10 is void of a secondary backing layer.

[0110] In an embodiment, the artificial turf system 10 includes an infill material 60. The infill is a particulate material and is arranged between individual turf yarns. Infill material 60 performs one, some, or all of the following:

- (1) keeps individual turf yarns upright; and/or
- (2) protects the primary backing layer from direct sunlight, thereby increasing the lifespan of the primary backing layer; and/or
- (3) increases the ballast to prevent matting, ensuring the individual yarns spring back after heavy traffic.

[0111] Nonlimiting examples of suitable materials for the infill material 60 include sand (silica), coated silica sand, SBR (styrene butadiene rubber), recycled rubber from car tires, EPDM (ethylene-propylene-diene monomer), other vulcanised rubbers or rubber recycled from belts, thermoplastic elastomers (TPEs) and thermoplastic vulcanizates (TPVs), crumb rubber, and any combination thereof.

[0112] Nonlimiting examples of other suitable materials for the infill material 60 include organic material such as natural cork, ground fibers from the outside shell of the coconut, and any combination thereof.

[0113] In an embodiment, the artificial turf system 10 includes a drainage component 70. The drainage component allows water to be removed from the artificial turf and prevents the artificial turf yarns from becoming saturated with water. Nonlimiting examples of suitable drainage components include stone-based drainage systems, EXCELDRAIN Sheet 100, EXCELDRAIN Sheet 200, AND EXCELDRAIN EX-T STRIP (available from American Wick Drain, Monroe, North Carolina).

[0114] In an embodiment, the shock absorption component 20 has dimensions of 305 mm × 305 mm × 54 mm (shockpad 48 mm, cushioning layer 6 mm) (hereafter SAC1 as shown in Table 1). SAC1 has one, some, or all of the following properties (i)-(ix):

- (i) a shockpad tensile strength from 10N, or 30 N, or 40 N to 80 N, or 300 N, or 500 N; and/or
- (ii) a shock absorption component tensile strength from 30 N, or 50 N, or 100 N to 250 N, or 600 N, or 800N; and/or
- (iii) a shockpad ILD (25%) from 20 N, or 30 N, or 60 N to 130 N, or 400 N, or 500N; and/or
- (iv) a shock absorption component ILD (25%) from 30 N, or 50 N, or 100 N to 250 N, or 600 N, or 800N; and/or
- (v) a shockpad ILD (65%) from 50 N, or 100 N, or 200 N to 300 N, or 400 N, or 600 N; and/or
- (vi) a shock absorption component ILD (65%) from 75 N, or 150 N, or 250 N to 700 N, or 1000 N, or 1200 N; and/or
- (vii) a shockpad porosity from 80%, or 90%, or 93% to 99.5 %, or 97%, or 99%; and/or
- (viii) a cushioning layer porosity from 0%, or greater than 0%, or 50%, or 70% to 80%, or 90%, or 95 %; and/or
- (ix) a shock absorption component porosity from 80%, or 85%, or 90% to 95%, or 99%, or 99.5%

[0115] The present artificial turf system 10 advantageously provides the following benefits.

(1) Improved drainage. The open loop structure of the cushioning layer 40 and the shockpad 50 provides a high capacity for drainage of rain water both vertically and horizontally due to the open three-dimensional structure of the shock absorption component 20 composed of 3DRLM 30.

(2) Infill reduction. The shock absorption component 20 increases the shock absorption and resiliency of the artificial turf system 10, reducing the amount of infill material 60 needed. The reduction of infill material usage enables lower maintenance work, lower risk of injury due to inhomogeneous distribution of granules, and lowers cost of the overall artificial turf system.

(3) Improved recyclability. An all-polyolefin artificial turf system is enabled by present artificial turf system 10 with the inclusion of (i) the primary backing layer 12 that is a propylene-based polymer, (ii) the shock absorption component 20 that is composed of an ethylene-based polymer, and (iii) an elastomeric polymer infill material that is an ethylene-based polymer. The "all-polyolefin" artificial turf system 10 can be recycled in one single polymeric stream, rather than treating separately the polyethylene yarn, the PU/SB latex secondary backing, as is the case with incumbent artificial turfs-i.e., artificial turf with SBR/sand infill and a polyurethane shock pad.

(4) Reduction in manufacturing cost. The integration of shock pad 50 and cushioning layer 40 in one single integral shock absorption component 20 eliminates the production step of applying a secondary backing layer to the system, creating production efficiency and lowering the overall cost of the present artificial turf system 10.

[0116] By way of example, and not limitation, some embodiments of the present disclosure will now be described in detail in the following Examples.

Examples

1. Materials

[0117] A shock absorption component having a cushioning layer integral with the shock pad is produced on a C-ENG line (Duralastic, US). The formant shock absorption component has the structure of the shock absorption component 20 shown in FIG. 2 with cushioning layer 40 and shock pad 50. The 3DRLM of the formant shock absorption component is continuous fibers composed of an ethylene/octene α -olefin copolymer having a density of 0.905 g/cc.

[0118] Table 1 below provides the properties for the formant shock absorption component (hereafter referred to as SAC1).

Table 1 -SAC1 properties

SAC1	Nominal Dimensions = 305mm × 305mm × 54mm
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(continued)

SAMPLE	Mass (g)	Thickness (mm)	Volume (cc)	Density (g/cc)	Porosity (%)
Shock Absorption Component	310.1	54	5016.8	0.0618	93.17%
Shock Pad	187.9	48	4459.3	0.0421	95.34%
Cushioning Layer	122.2	6	557.4	0.2192	75.78%
Control 3DL Sample				0.0626	93.08%
Solid PE				0.905	0.00%

2. Testing

[0119] The performance of SAC1 is compared to a control (comparative sample, or CS). The control sample is the shockpad shown in Table 1 above. In other words, the control sample is composed of the same 3DRLM as SAC1, the difference being that the control sample is the shockpad only; the control sample has cushioning layer cut off and physically removed. SAC1 includes both the shockpad and the cushioning layer.

[0120] The control sample and SAC1 sample, are prepared for ILD testing and tensile strength testing. The sample for the shock absorption component is 381mm × 381mm × 54 mm. From this sample, a test sample is cut with dimensions 305mm × 305mm × 54mm for compression testing. The compression test is non-destructive. After the compression test for the shock absorption component, specimens are prepared for tensile strength testing. Four samples are cut from the 381mm × 381mm × 54 mm sample of the shock absorption component. The specimens used for the tensile test are 203 mm long and 32.7 mm wide. The tensile test is a destructive test. Two of these tensile specimens are measured for the shock absorption component (cushioning layer integral to shockpad). For the two other tensile specimens, the cushioning layer is cut from the shockpad, and the shockpad alone (control) is subjected to the tensile test.

[0121] The results are provided in Table 2 below.

Table 2. ILD and tensile test results

	ILD (N) 25% compress	ILD (N) 65% compress	Tensile strength (N)
Control CS*	87.6	228	66
SAC1 (inventive)	133	424	158
*shockpad only, cushioning layer removed from shock absorption component			

[0122] Applicant discovered that the 3DRLM shock absorption component with integral cushioning layer and shockpad (i.e., SAC1) unexpectedly exhibits improved shock absorption (ILD 65% 424 SAC1 vs 228 control) and improved tensile strength (158N SAC1 vs 66N control) when compared to 3DRLM shockpad only.

Claims

1. An artificial turf system (10) comprising:

a primary backing layer (12) having a plurality of artificial turf yarns (14) projecting upwardly from the primary backing layer (12) having a bottom surface;

a shock absorption component (20) composed of a sheet of three-dimensional random loop material (3DRLM (30)) and in contact with the primary backing layer (12), the shock absorption component (20) comprising

- (i) a cushioning layer (40) having an exposed surface; and
- (ii) a shockpad (50); and

wherein the 3DRLM (30) in the cushioning layer (40) has an apparent density that is greater than the apparent density of the 3DRLM (30) in the shockpad (50) and

wherein the exposed surface of the cushioning layer (40) contacts the bottom surface of the primary backing layer (12).

2. The artificial turf system (10) of claim 1 wherein the cushioning layer (40) is integral to the shockpad (50).
3. The artificial turf system (10) of claim 2 wherein the 3DRLM (30) comprises a plurality of multiple loops (32) formed by a plurality of continuous fibers (34) composed of polymeric material; and at least two continuous fibers extend from the shockpad (50) to the cushioning layer (40).
4. The artificial turf system (10) of claim 1 wherein the shockpad (50) has a thickness, measured in millimeters, from 2 times to 300 times greater than the thickness of the cushioning layer (40).
5. The artificial turf system (10) of claim 4 wherein the apparent density of the cushioning layer (40) is from 2 times to 400 times greater than the apparent density of the shockpad (50).
6. The artificial turf system (10) of claim 1 wherein the shockpad (50) has an apparent density from 0.010 g/cc to 0.400 g/cc.
7. The artificial turf system (10) of claim 6 wherein the cushioning layer (40) has an apparent density from 0.030 g/cc to 1.000 g/cc.
8. The artificial turf system (10) of claim 1 wherein the 3DRLM (30) is composed of an ethylene-based polymer.
9. The artificial turf system (10) of claim 1 comprising an infill material (60).
10. The artificial turf system (10) of claim 9 wherein the turf yarn (14), the primary backing layer (12), the 3DRLM (30), and the infill material (60) each is composed of an olefin- based polymer.

Patentansprüche

1. Kunstrasensystem (10), umfassend:

eine primäre Trägerschicht (12) mit einer Vielzahl von Kunstrasengarnen (14), die von der primären Trägerschicht (12) nach oben vorstehen, die eine untere Oberfläche aufweist;
eine Stoßdämpfungskomponente (20), die aus einer Lage eines dreidimensionalen Zufallsschlaufenmaterials (3DRLM (30)) besteht und mit der primären Trägerschicht (12) in Berührung ist, die Stoßdämpfungskomponente (20) umfassend

- (i) eine Polsterschicht (40), die eine freiliegende Oberfläche aufweist; und
- (ii) ein Shockpad (50); und

wobei das 3DRLM (30) in der Polsterschicht (40) eine scheinbare Dichte aufweist, die größer als die scheinbare Dichte des 3DRLM (30) in dem Shockpad (50) ist und

wobei die freiliegende Oberfläche der Polsterschicht (40) die untere Oberfläche der primären Trägerschicht (12) berührt.

2. Kunstrasensystem (10) nach Anspruch 1, wobei die Polsterschicht (40) einstückig mit dem Shockpad (50) ist.
3. Kunstrasensystem (10) nach Anspruch 2, wobei das 3DRLM (30) eine Vielzahl von mehreren Schlaufen (32) umfasst, die durch eine Vielzahl von Endlosfasern (34) ausgebildet sind, die aus Polymermaterial bestehen; und mindestens zwei Endlosfasern sich von dem Shockpad (50) zu der Polsterschicht (40) erstrecken.
4. Kunstrasensystem (10) nach Anspruch 1, wobei das Shockpad (50) eine Dicke, gemessen in Millimetern, von 2 Mal bis 300 Mal größer als die Dicke der Polsterschicht (40) aufweist.
5. Kunstrasensystem (10) nach Anspruch 4, wobei die scheinbare Dichte der Polsterschicht (40) von 2 Mal bis 400 Mal höher als die scheinbare Dichte des Shockpads (50) ist.

6. Kunstrasensystem (10) nach Anspruch 1, wobei das Shockpad (50) eine scheinbare Dichte von 0,010 g/cm³ bis 0,400 g/cm³ aufweist.
7. Kunstrasensystem (10) nach Anspruch 6, wobei die Polsterschicht (40) eine scheinbare Dichte von 0,030 g/cm³ bis 1.000 g/cm³ aufweist.
8. Kunstrasensystem (10) nach Anspruch 1, wobei das 3DRLM (30) aus einem Polymer auf Ethylenbasis besteht.
9. Kunstrasensystem (10) nach Anspruch 1, umfassend ein Auffüllmaterial (60).
10. Kunstrasensystem (10) nach Anspruch 9, wobei das Rasengarn (14), die primäre Trägerschicht (12), das 3DRLM (30) und das Auffüllmaterial (60) jeweils aus einem Polymer auf Olefinbasis bestehen.

Revendications

1. Système de gazon artificiel (10) comprenant :

une couche de support principale (12) ayant une pluralité de fils de gazon artificiel (14) faisant saillie vers le haut à partir de la couche de support principale (12) ayant une surface inférieure ;
un composant d'absorption de chocs (20) composé d'une feuille de matériau à boucles aléatoires tridimensionnelles (3DRLM (30)) et en contact avec la couche de support principale (12), le composant d'absorption de chocs (20) comprenant

- (i) une couche d'amortissement (40) ayant une surface exposée ; et
- (ii) un tapis antichoc (50) ; et

dans lequel le 3DRLM (30) dans la couche d'amortissement (40) a une masse volumique apparente qui est supérieure à la masse volumique apparente du 3DRLM (30) dans le tapis antichoc (50) et
dans lequel la surface exposée de la couche d'amortissement (40) vient en contact avec la surface inférieure de la couche de support principale (12).

2. Système de gazon artificiel (10) selon la revendication 1 dans lequel la couche d'amortissement (40) est solidaire du tapis antichoc (50).

3. Système de gazon artificiel (10) selon la revendication 2 dans lequel le 3DRLM (30) comprend une pluralité de boucles multiples (32) formées par une pluralité de fibres continues (34) composées de matériau polymère ; et au moins deux fibres continues s'étendent du tapis antichoc (50) à la couche d'amortissement (40).

4. Système de gazon artificiel (10) selon la revendication 1 dans lequel le tapis antichoc (50) a une épaisseur, mesurée en millimètres, allant de 2 fois à 300 fois supérieure à l'épaisseur de la couche d'amortissement (40).

5. Système de gazon artificiel (10) selon la revendication 4 dans lequel la masse volumique apparente de la couche d'amortissement (40) va de 2 fois à 400 fois supérieure à la masse volumique apparente du tapis antichoc (50).

6. Système de gazon artificiel (10) selon la revendication 1 dans lequel le tapis antichoc (50) a une masse volumique apparente allant de 0,010 g/cm³ à 0,400 g/cm³.

7. Système de gazon artificiel (10) selon la revendication 6 dans lequel la couche d'amortissement (40) a une masse volumique apparente allant de 0,030 g/cm³ à 1,000 g/cm³.

8. Système de gazon artificiel (10) selon la revendication 1 dans lequel le 3DRLM (30) est composé d'un polymère à base d'éthylène.

9. Système de gazon artificiel (10) selon la revendication 1 comprenant un matériau de remplissage (60).

10. Système de gazon artificiel (10) selon la revendication 9 dans lequel le fil de gazon (14), la couche de support principale (12), le 3DRLM (30), et le matériau de remplissage (60) sont composés chacun d'un polymère à base d'oléfine.

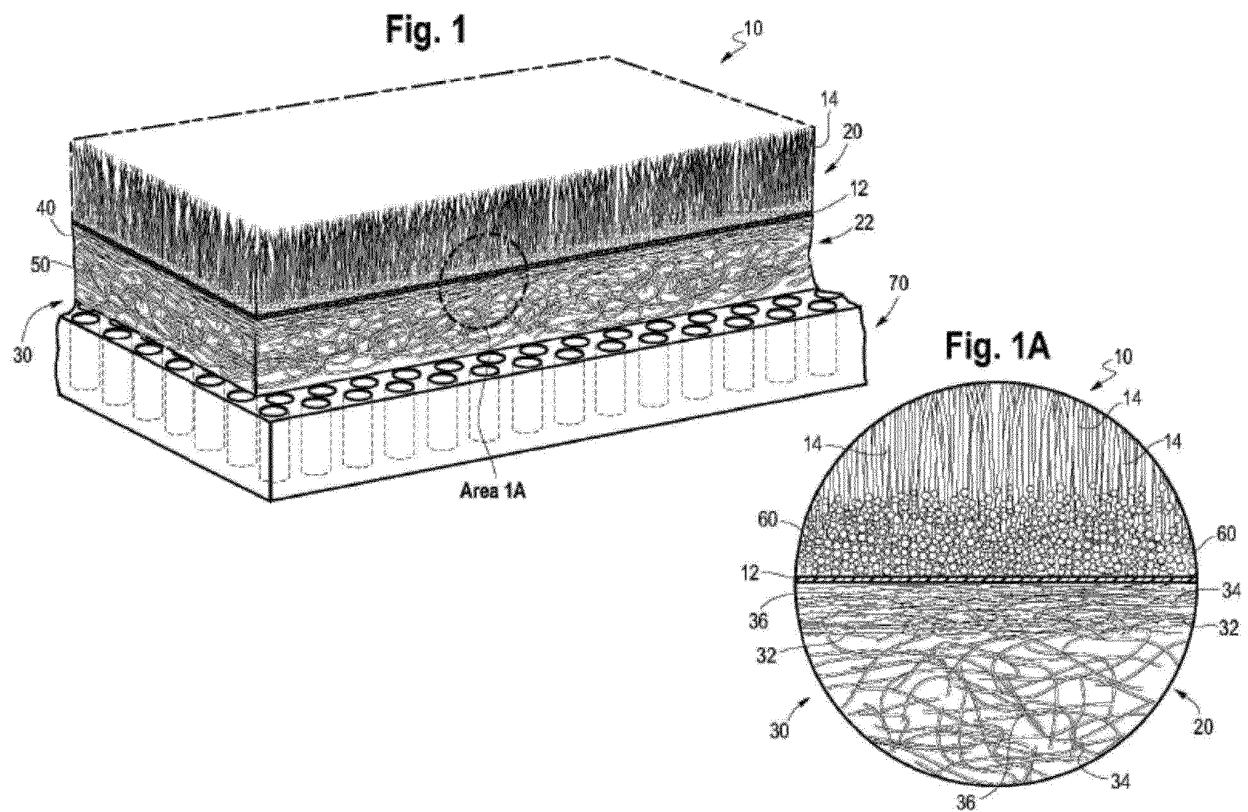
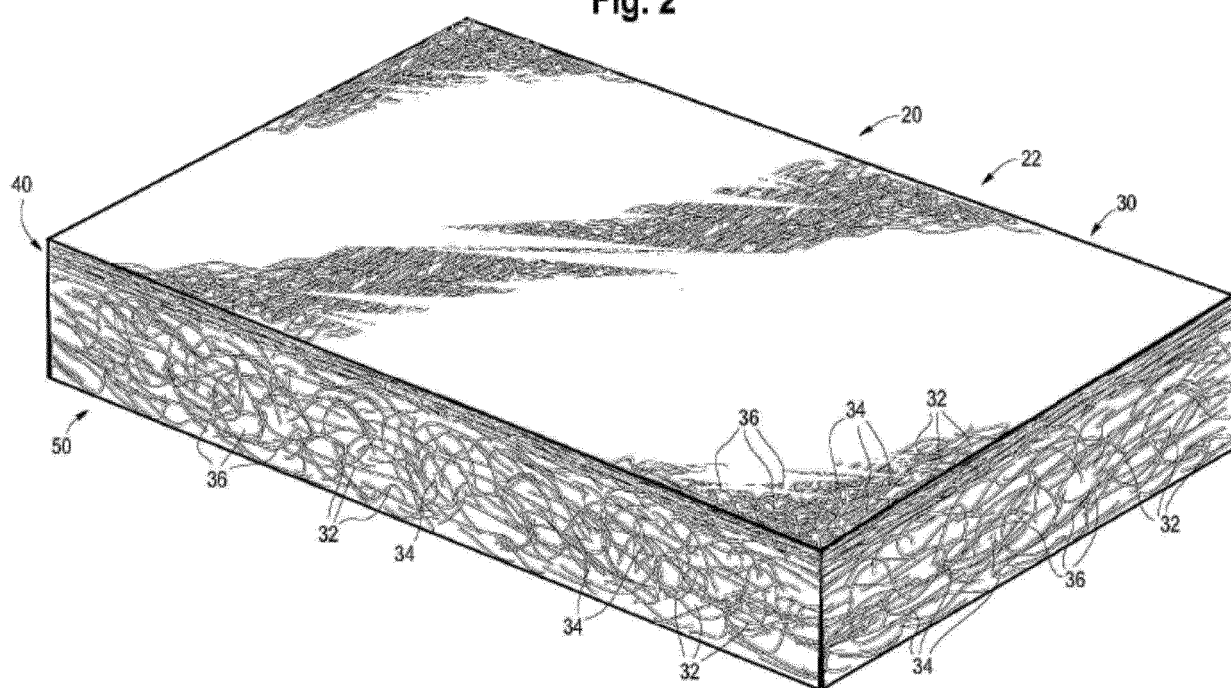


Fig. 2



REFERENCES CITED IN THE DESCRIPTION

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