(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) **EP 3 315 640 A1**

(12) **EUROPEAN PATENT APPLICATION**

(43) Date of publication:
02.05.2018 Bulletin 2018/18

(51) Int Cl.:
D01F 6/46 *(2006.01)* ***E01C 13/08*** *(2006.01)*

(21) Application number: **16196633.8**

(22) Date of filing: **31.10.2016**

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA ME
Designated Validation States:
MA MD

(71) Applicant: **Polytex Sportbeläge Produktions-GmbH**
47929 Grefrath (DE)

(72) Inventors:
- **NEUHOFF, Ulrich**
  47228 Duisburg (DE)
- **SICK, Stephan**
  47877 Willich (DE)
- **LOHR, Ivo**
  47906 Kempen (DE)
- **SANDER, Dirk**
  47647 Kerken (DE)
- **JANSEN, Bernd**
  41334 Nettetal (DE)
- **HALLY, Stefan**
  41334 Nettetal (DE)

(74) Representative: **Richardt Patentanwälte PartG mbB**
Wilhelmstraße 7
65185 Wiesbaden (DE)

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

(54) ARTIFICIAL TURF FIBER FROM RENEWABLE POLYETHYLENE

(57) The invention relates to a method of manufacturing artificial turf (200), the method comprising:
- creating (102) a polymer mixture (300, 400, 500) comprising
• a first polymer (304; 404;504) in an amount of at least 57% by weight of the polymer mixture, wherein a portion (304, 404, 506) of at least 30 % by weight of the first polymer is made from the renewable carbon source; and
• a second polymer (302; 402, 502) in an amount of at least 8 % by weight of the polymer mixture, the second polymer being HDPE;
- extruding (104) the polymer mixture;
- generating (106) the artificial turf fibers (202) from the extruded polymer mixture.

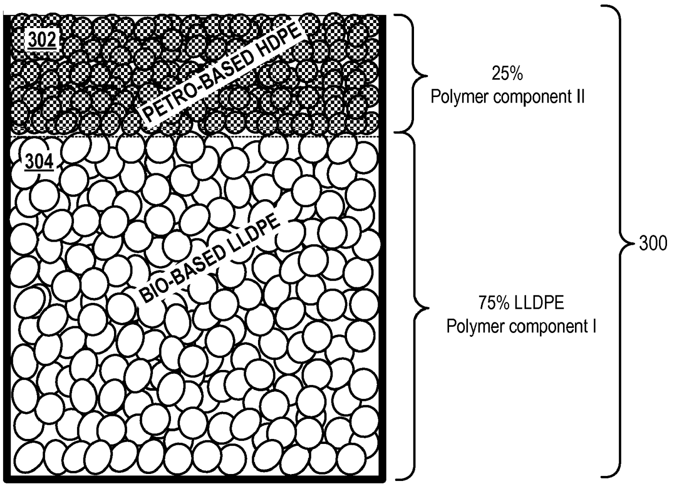


Fig. 4

Printed by Jouve, 75001 PARIS (FR)

Description

Field of the invention

[0001] This invention relates to artificial turf, and more particularly to a sustainable artificial turf production method.

Background and related art

[0002] Artificial turf is a surface of synthetic fibers that is commonly made to look like natural grass. It is often used in arenas for sports that were originally or are normally played on natural grass. However, other applications are known as well, e.g. privately owned gardens and courtyards.

[0003] Artificial turf does not need to be irrigated or trimmed and has many other advantages regarding maintenance effort and other aspects. Irrigation can be difficult due to regional restrictions for water usage. In other climatic zones the regrowing of grass and re-formation of a closed grass cover is slow compared to the damaging of the natural grass surface by playing and/or exercising on the field. Artificial turf does not need sunlight and thus can be used at places where there is not enough sunlight to grow natural grass. To ensure that artificial turf replicates the playing qualities of good quality natural grass, artificial turf needs to be made of materials which will not increase the risk of injury to players and which are of adequate durability. Many fields are subjected to very high intensity use relating to player-to-surface interactions and ball-to-surface interaction. The surface of the artificial turf fibers must be smooth enough to prevent injuries to the skin of the players when sliding on the surface, but at the same time must be (sufficiently embedded into the substructure to prevent the fibers from, e. g. being pulled out of the carrier if a strong tuft withdrawal force is applied. Thus, the materials used for producing artificial turf must have highly specific properties regarding smoothness, brittleness, resistance to shear forces etc.

[0004] The majority of chemicals currently used for manufacturing artificial turf are petrochemical substances originating from crude oil or petroleum oil or natural gas.

[0005] They are products of the refinery process of petroleum oil. The use of petroleum oil is problematic as a non-renewable energy source is consumed.

[0006] Although meanwhile some few types of "bioplastics" exist on the market which are manufactured from renewable sources of biomass, the properties of these bioplastics are not suited for producing artificial turf with the desired properties.

[0007] Polymeric material for the preparation of artificial turf fibers is versatile. Polyethylene has shown advantageous in comparison with other polymers. Particularly, linear polyethylene (LLDPE and HDPE) offers a wide range of physical material properties, covering the technical requirements of artificial turf fibers. The density of linear polyethylene can be widely modified by co-monomers. The molecular weight distribution can be controlled with catalysts and by polymerization process management. Catalysts can be of the multi-site species or of the single-site species. Multi-site catalysts are also referred to as Ziegler, Ziegler-Natta or Phillips catalysts. Single-site catalysts are also referred to as metallocene catalysts. The use of multi-site catalysts results in polymers with relatively broad molecular weight distributions and co-monomer distributions compared with single-site catalysts. Blending different types of polyethylene in situ, i. e. inside the polymerization reactor, or ex situ, i. e. after polymerization, broadens the variety further.

[0008] For example, EP1378592 (Slootweg et al.) suggests a blend for artificial turf fibers comprising a first polymer with a bimodal molecular weight distribution and a second polymer; the first polymer being a plastomer with very low density and the second polymer being HDPE.

[0009] WO2006066777 (Lambert et al.) teaches the manufacture of fibers made from blends; one component having a density of 920 to 940 g/l and the other component having a density of 900 to 960 g/l with a difference in density of no more than 20 g/l.

[0010] WO2008113566 (Van Paridon et al.) describe single-site metallocene LLDPE with densities of less than 980 g/l and unimodal or bimodal molecular weight distribution as suitable for fiber preparation.

[0011] WO2008098905 (Buriani et al.) describe blends of HDPE and very low density PE, the HDPE having a density of 930 to 965 g/l and the VLDPE having a density of 868 g/l.

[0012] WO2011134897 (Perdomi et al.) describe blends of a first component, being a plastomer with densities lower than 900 g/l and a second component, being LLDPE with densities in a range of 900 to 945 g/l.

[0013] WO2012005974 (Sandkuehler et al.) describe a blend of three components; the first being a metallocene LLDPE with densities from 850 to 905; the second being a Ziegler-LLDPE with densities from 910 to 945 and the third being HDPE with densities of greater than 945 g/l.

[0014] All of the described blends have proven unsatisfactory, concerning the dimensional stability of the fibers made from those blends. The dimensional instability causes the fibers to bend, curl and shrink under the influence of heat or mechanical stress.

[0015] There is still a need to overcome these shortcomings by developing specific blends with improved properties and with a particular sight on the application of bioplastics.

Summary

[0016] It is an objective of the present invention to provide an improved method of manufacturing artificial turf and a corresponding artificial turf as specified in the independent claims. Embodiments of the invention are given in the dependent claims. Embodiments of the present invention can be freely combined with each other if they are not mutually exclusive.

[0017] In a first aspect, the invention relates to a method of manufacturing artificial turf fibers which consist at least partially of a polymer made from a renewable carbon source. The method comprises creating a polymer mixture which comprises a first polymer and a second polymer. The polymer mixture comprises the first polymer in an amount of at least 57% by weight of the polymer mixture. A portion of at least 30 % by weight of the first polymer is made from the renewable carbon source. The polymer mixture comprises the second polymer in an amount of at least 8 % by weight of the polymer mixture. The second polymer is HDPE.

[0018] Said features may be advantageous for multiple reasons:

> In one aspect, a downside of artificial turf is overcome: conventional artificial turf production is based on the use of petrochemicals for producing the fiber material and sometimes also the backing material. The consumption of petroleum or natural gas for producing the PE for the fibers depletes the natural stock of petroleum oil and causes carbon dioxide release at the end of life incineration. Carbon dioxide emissions are responsible for the global warming process by the greenhouse gas effect. By using PE made from renewable carbon source, the depletion of the natural stock of petroleum is avoided or at least reduced. Moreover, as the biobased PE is made from renewable resources, the generated artificial turf may even deplete the earth atmosphere from CO_2 as the CO_2 contained in the renewable carbon source is bound in the form of artificial turf fibers. Thus, in some cases a negative CO_2 footprint may be achieved by manufacturing and installing artificial turf. Making use of bio-based chemicals may decelerate global warming. By using biobased polymers instead of petrobased polymers for artificial turf production, the atmosphere is mitigated of CO_2 as the CO_2 that is bound in the renewable carbon source used for generating the bio-based polymer that is now bound in the fibers of the artificial turf. Thus, producing "biobased" artificial turf may reduce dependency on fossil fuels, reduce the amount of CO_2 in the atmosphere and save oil resources for other applications.

[0019] The use of biobased PE for artificial turf production was hitherto technically not feasible: throughout the typical usage time of 5-15 years, an artificial turf sports field must withstand high mechanical wear, must resist UV-radiation, must withstand thermal cycling or thermal ageing, must resist interactions with the players, sports equipment, chemicals and various environmental impacts. The fibers of an artificial turf are heavily exposed to mechanical stress like kicking, jumping, slipping, etc. and environmental impact like temperature changes, ozone, sunlight irradiation, etc. Therefore, the material of the fibers has to be chosen well in order to withstand that kind of stress for a long period, which means it should be rigid and chemically stable. On the other hand the material should be soft enough to inhibit skin abrasions and irritations when rubbing on the surface. Rigidity and softness are excluding properties. Rigid polymers are not soft and vice versa. That means the properties have to be balanced out thoroughly.

[0020] While a huge variety of petrobased polymers exist allowing manufacturers to simply order a PE variant with the desired properties, the market for biobased polymers is still comparatively small and only a very limited number of bio-based polymers exists. Available bio-based polymers do not have the desired properties to suit for the production of artificial turf fibers without modification. That means, plastic converters have to develop polymer mixtures or blends to create a suitable material. Although the density of the bio-based LLDPE is in the same range as the petro-based comparator, they differ to some extent in their mechanical properties and wear resistance. In particular, properties like tensile strength and tear resistance of bio-based PE are not in the desired range. This would cause breakdown of the fibers at an early stage of usage when the fibers would be generated from pure bio-based polymers.

[0021] Applicant has surprisingly observed that by mixing a specific amount of HDPE (referred herein as the "second polymer") with a specific (and larger) amount of a PE manufactured at least partially from a renewable carbon source, a polymer blend is provided which is suited for being used in artificial turf fiber production. The resulting artificial turf comprising biobased-PE fibers has a long usable life, is durable, and keeps its playing and surface characteristics as well as appearance throughout its usage time. Without the intention to be bound by any theory, applicant believes that the specific combination of the first and the second polymers described herein for embodiments of the invention provide a good compromise between softness and rigidity of the PE fibers. On a molecular scale the rigidity or the hardness of polyethylene correlates with the crystallinity and the softness correlates with the amorphousness. Crystalline and amorphous states are also excluding each other. The more crystalline something is the less amorphous it is. Polyethylene consists of material in both states, i. e. crystalline matter embedded in an amorphous phase. The resistance to tensile forces and shear forces may also depend on the branching pattern of the PE molecules, i.e., the number and length of the branches of a PE molecule. By mixing the specified amounts of a first polymer, e.g. LLDPE, that is completely or largely made from a renewable carbon source, and HDPE, a polymer blend is provided whose rigidity, softness and resistance to tensile and shear forces is suitable for producing artificial turf fibers that are largely based on bio-PE.

[0022] Combining a first and a second PE type may be advantageous as the physicochemical properties of the fiber depend on the properties of two different polymers. With only one component the filaments might lack either tensile strength or wear resistance.

[0023] Embodiments of the invention may allow producing bio-PE based artificial turf fibers having the same or almost the same physical properties as the conventional petro-based fibers. Embodiments of the invention may also allow the manufacturing of bio-fibers (artificial turf fiber comprising a significant portion, e.g. 20 % by weight, polymers derived from a renewable carbon source) and petrobased fibers on the same extruder lines and at the same draw ratios, relaxation and/or texturing equipment as used for processing the petrobased fibers. Embodiments of the invention may also allow the same haul-off speeds, i. e. the mass output at the extruder die face without melt fraction of the bio-based fibers.

[0024] The renewable carbon source can be, for example, biomass. The biomass can be, for example, sugarcane, sugar beet, wheat grain, organic household waste, plant waste products, industrial organic waste of any kind, and others. Likewise, the material for the generation of PE may also originate from other renewable, non-fossil carbon sources, e.g. CO_2, which itself cannot be referred to as biomass. The preparation of chemicals from CO_2 is a relatively new approach of solving the global warming problem.

[0025] In the following, any kind of carbon source that is used for producing a material whose ^{14}C atom content is similar or basically identical to the ^{14}C content of biomass of recently living organisms is referred to as renewable carbon source.

[0026] Atmospheric CO_2 is the source of radioactive carbon C14. Fossil (petro-based) carbon sources comprise a lower amount of radioactive C14 isotopes and thus can be discerned from bio-based carbon sources by performing an isotope analysis (radiocarbon dating). Roughly half of all ^{14}C atoms decay after 5700 years. Suitable carbon sources for the bio-based polymer mixture may be a manufacturing process or any other natural or man-made material or process that can be used to produce a chemical substance.

[0027] According to embodiments, the first polymer is a linear low density polyethylene (LLDPE).

[0028] According to embodiments, the first polymer or at least a part of the first polymer is not one of the typically used and conventionally manufactured 1-olefin co-monomer based LLDPEs.

[0029] Conventionally produced LLDPE is derived from ethylene originating from crude oil or natural gas. It is a product of the petrochemical refinery process.

[0030] On the contrary, bio-based LLDPE is derived from biomass or another renewable carbon source. For example, the bio-based LLDPE can be derived from bio-based ethanol by converting the ethanol into bio-ethylene in a dehydration reaction. For some references on ethanol dehydration for generating bio-ethylene from bio-ethanol, see for example "Ethylene formation by catalytic dehydration of ethanol: industrial considerations", Denise Fan, Der-Jong Dai, and Ho-Shing Wu, Materials, 6, 101-115 (2013); or "Catalytic dehydration of bioethanol to ethylene over TiO2/γ-Al2O3 catalysts in microchannel reactors", G. Chen, S. Li, F. Jiao, and Q. Yuan, Catalysis Today, 125, 111-119(2007). The amount of ethanol needed to make one metric ton of bio-PE is roughly two metric tons, as dehydration takes a part of the weight in water from the sugar cane based ethanol. An important environmental benefit of bio-PE is the sequestration of roughly 2,15 ton of CO_2 per ton of bio-PE produced, which comes from the CO_2 absorbed by the sugar cane while growing, minus the CO_2 emitted through the production process.

[0031] It has shown advantageous to use LLDPE with 1-octene as the co-monomer for the preparation of blends for artificial turf fibers resulting in better tear resistance when compared with 1-hexene or 1-butene LLDPE in the density range between 916 and 920 g/l. As bio-based ethylene molecules do not differ from petrochemical comparators, despite the fact that biomass was the origin, the co-monomers seem to determine the mechanical properties of LLDPE-fibers. In addition, the process of manufacturing currently available bio-based LLDPEs significantly differs from the process used for generating petro-based LLDPE with 1-octene as co-monomer. As a consequence, also the physicochemical properties of bio-LLDPE and petro-LLDPEs on the market significantly differ from each other. As mentioned above, the currently available bio-LLDPE types are not suitable for manufacturing artificial turf fibers. Applicant has surprisingly observed that my mixing bio-LLDPE with bio- and/or petro-based HDPE in a defined ratio yields a polymer blend that has the desired material properties.

Bio-based LLDPE

[0032] According to embodiments, the portion of the first polymer that is made from the renewable carbon source is a Ziegler/Natta catalyzed, gas-phase polymerized LLDPE generated from mixtures of polymerization educts. The polymerization educts comprise ethylene as the main monomer and a co-monomer. The co-monomer is 1-butene and/or 1-hexene. Preferentially, the co-monomer or co-monomer mixture used for generating the bio-LLDPE portion is basically free of 1-octene or higher molecular monomers. According to one embodiment, the co-monomer is contained in the polymerization educt mixture in an amount of 12-14% by weight of the polymerization mixture.

[0033] According to embodiments, the portion of the first polymer that is made from the renewable carbon source is a linear low density polyethylene LLDPE having a density of 0.916 to 0.920 g/ml and a melt flow rate of 2 to 4 g/10 min at 190 °C / 2.16 kg.

[0034] While bio-based ethylene molecules do not differ from petrochemical comparators, the renewable LLDPE available on the market significantly differs from petro-based LLDPE, because petro-based LLDPE can be generated in a co-polymerization reaction with octene (which may optionally further comprise a minor fraction of "smaller" co-monomers like butene or hexene). Currently, the 1-octene-co-polymers available are all petro-based. Usually 1-octene co-polymers are produced in a solution polymerization process, whereas butene and hexene co-polymers are produced in gas-phase reactors.

[0035] Manufacturers of bio-based LLDPE use gas-phase reaction techniques which has the effect that the renewable carbon content in their products is increased by using

[0036] (petro-based) co-monomers having only 4 or 6 rather than 8 or more carbon atoms. Thus, the bio-LLDPE on the market today is largely generated from bio-ethylene in a co-polymerization process with 1-butene, optionally also 1-hexene, but basically without 1-octene or higher 1-olefines for increasing the fraction of "bio-based" carbon atoms in the product. The use of 1-butene or 1-hexene instead of 1-octene as a co-monomer for generating bio-LLDPE has a significant impact on the material properties of the resulting bio-LLDPE.

[0037] According to embodiments, the bio-LLDPE is generated in a gas-phase process, whereby 1-butene and/or 1-hexene are used as co-monomers. According to embodiments, the gas-phase polymerization process is a "Spherilene"-process (LyondellBasell) which can be run with one reactor (Spherilene S) for unimodal polymers or in two reactors in series (Spherilene C) for unimodal or bimodal polymers. Catalysts can be, for example, Ziegler-Natta catalysts like Avant Z (Ziegler) or Avant C (Phillips). As the process of manufacturing currently available bio-based LLDPEs significantly differs from the process used for generating petro-based LLDPE with 1-octene as co-monomer, the physicochemical properties of bio-LLDPE also differ and are less suited for use in artificial turf fiber production.

[0038] (In general, bio-LLDPE differs from petrobased LLDPE in that a smaller weight fraction of co-monomers (1-butene, 1-hexene) is incorporated in the polymeric material compared to conventionally produced, petrobased 1-octene LLDPE. This is because said co-monomers are synthesized from bio-alcohol. They are synthesized from crude oil. Thus, even "bio"-LLDPE does not completely consist of carbon atoms derived from renewable sources as the co-monomers used in the co-polymerization are petrobased. However, up to 87 wt% of a bio-PE consists of renewable sources in 1-butene co-polymers and up to 84 wt% in 1-hexene co-polymers. As 1-butene consists of 4 carbon atoms while 1-hexen consists of 6 carbon atoms, this explains the difference in the "bio-content" of LLDPEs. However, the use of 1-butene instead of 1-octene results in a reduced length of the side chains. This has a negative impact on the stiffness.

[0039] Using a co-monomer for producing the bio-LLDPE may be advantageous as the plastification of polymeric materials, i.e. the flexibility of the polymer, is increased. Polymerizing a co-monomer together with ethylene lowers the density of the resulting polymer. In general, every 1-olefin or α-olefin can act as a co-monomer in the polymerization process, but for the above mentioned reasons, typically only 1-butene or 1-hexene is in use for copolymerization of bio-LLDPE. As these molecules carry a double bond between two carbon atoms, it is possible to insert them instead of an ethylene molecule into the growing chain of the macromolecule which forms in the polymerization process. The incorporation of a 1-olefin molecule into the polymer main chain leaves, other than ethylene does, a side chain on the main chain.1-butene, for instance, includes 4 carbon atoms and generates an ethyl side chain, whereas two carbon atoms (the two with the double bond between carbon atoms 1 and 2) are incorporated into the main chain and another two carbon atoms extent outwardly of that main chain as a side chain. In case of hexene the length of the side chain is 4 carbon atoms and it is 6 with octene. The number and the length of the side chain branching determine the density of LLDPE and thereby other physicochemical properties. Depending on the design of the polymerization process the side chain branching is heterogeneous or homogeneous. In heterogeneously branched macromolecules the distance from one branching point to another branching point is broadly distributed along the polymer main chain. The other way round, the branches are more evenly spaced in homogeneous branched LLDPEs.

[0040] Concerning the side chain distribution, the molecular architecture may greatly be influenced by the choice of the catalyst used in the polymerization process. Ziegler catalysts, also referred to as Ziegler-Natta catalysts or multi-site catalysts, yield in heterogeneously branched polymers, whereas metallocene catalysts, also referred to as single-site catalysts, yield in homogeneously branched polymers. It has also been observed that with Ziegler catalysts the co-monomers are preferably incorporated into the short length main chains, while the longer main chains deplete of co-monomers.

[0041] Number, length and distribution of the side chains in PE macromolecules greatly influence the properties and the processability. According to applicant's experience, it is advantageous to use LLDPE with a broad distribution of side chains, typical for Ziegler-catalysed, solution polymerized polymers for turf fiber production, in particular for texturized turf fiber production. The fraction of short length polymer chains with high branching makes the fibers, produced of these LLDPE-types, easy to texturize. In the course of the texturizing process the fibers need to be softened under the influence of heat and then deformed, such that a wanted crimped shape results and stays on the fibers. It has turned out that the above mentioned LLDPE-types are appropriate for this process.

[0042] Although the bio-LLDPE has a different molecular architecture concerning the side chain branching pattern which has been often observed not to fulfill the requirements, and thus, alone is not suited for artificial turf production, it has been observed that by combining "standard bio-PE" with the second polymer, an artificial turf fiber having the desired properties can be produced, whereby the production process significantly reduces the depletion of petrol oil sources. Thus, artificial turf production companies (which typically do not operate refinery plants on their own) can order LLDPE being at least partially based on a renewable carbon source and combine it with HDPE for providing artificial grass fibers having the desired properties.

[0043] According to embodiments, the bio-portion of the LLDPE polymer is prepared from ethylene that was generated from biomass used as the renewable carbon source. In particular, the first polymer can be prepared from ethylene generated from bio-ethanol, whereby the bio-ethanol may be derived from biomass or another renewable carbon source. This may be advantageous as several well established procedures for generating bio-ethanol from various renewable organic sources are already known.

Petro-based LLDPE

[0044] According to embodiments, the first polymer does not completely consist of the bio-based LLDPE but rather comprises a further portion of LLDPE. The further portion consists of LLDPE made from fossil fuels. The further LLDPE portion is (a Ziegler/Natta catalyzed, solution polymerized LLDPE) generated from mixtures of polymerization educts. The polymerization educts comprise ethylene as the (main) monomer and a co-monomer. The co-monomer is 1-octene. According to embodiments, the co-monomer is contained in the polymerization polymer in an amount of less than 10 % by weight of the polymerization reaction mixture. According to embodiments, the further LLDPE portion consists of LLDPE made from fossil fuels and having a density of 0.930 to 0.940 g/ml and a melt flow rate of 2.5 to 5.5 g/10 min at 190 °C / 2.16 kg, and/or having a density of 0.915 to 0.919 g/ml and a melt flow rate of 2 to 4 g/10 min at 190 °C / 2.16 kg.

[0045] These above specified petro-based LLDPE forms have been observed to provide very good results for artificial turf which are not achievable by simply replacing the petro-based LLDPE with a similar amount of bio-LLDPE.

Petro-based HDPE

[0046] According to embodiments, the second polymer is petro based HDPE, i.e., it is HDPE made of fossil fuels.

[0047] According to embodiments, the second polymer is a Ziegler/Natta catalyzed, solution polymerized HDPE generated from mixtures of polymerization educts. The polymerization educts comprise ethylene as the main monomer and a co-monomer. The co-monomer is 1-octene.

[0048] According to embodiments, the second polymer is petro-based HDPE has a density of at least 0,950 g/ml, in particular a density within 0.952 to 0.955 g/ml, and a melt flow rate of 3 to 5 g/10 min at 190 °C / 2.16 kg.

Bio-based HDPE

[0049] According to other embodiments, the second polymer is a Ziegler/Natta catalyzed, gas-phase polymerized HDPE generated from mixtures of polymerization educts. The polymerization educts comprise ethylene as the main monomer and a co-monomer. The co-monomer is 1-butene.

[0050] According to other embodiments, the second polymer is a HDPE having a density of 0.948 to 0.962 g/ml and a melt flow rate of 0.2 to 20 g/10 min at 190 °C / 2.16 kg. A density of 0.948 to 0.959 g/ml and a melt flow rate of 4 to 5 g/10 min at 190 °C / 2.16 kg has been observed to be particularly advantageous.

[0051] According to other embodiments, the second polymer is a HDPE made from a renewable carbon source.

Various examples of LLDPE/HDPE blends comprising at least a bio-LLDPE portion

[0052] According to an embodiment, the portion of the first polymer being made from the renewable carbon source is within a range of 57 % and 87 % by weight of the polymer mixture. The amount of the second polymer being within a range of 8 % and 33 % by weight of the polymer mixture.

[0053] This blend may have the advantage that a high portion of the carbon atoms of the blend are derived from a renewable carbon source.

[0054] **Inventive** blend 1: According to one embodiment, the polymer mixture comprises:

- 65 % and 75 % by weight of the polymer mixture: the portion of the first polymer being made from the renewable carbon source;

- 5 % and 15 % by weight of the polymer mixture: a further portion of LLDPE having been made from fossil fuel.

- 15 % and 25 % by weight of the polymer mixture: the HDPE used as the second polymer.

[0055] For example, basically the whole LLDPE may consist of bio-LLDPE and the whole HDPE may consist of bio-HDPE or petro-HDPE. This embodiment may have the advantage that only two different polymer types may need to be added in the polymer mixture (typically, a master batch is added in addition). Thus, a simple formulation for the polymer mixture that can easily be prepared may be provided.

[0056] **Inventive blend 2:** According to one embodiment, the polymer mixture comprises:

- 75 % and 87 % by weight of the polymer mixture: the portion of the first polymer being made from the renewable carbon source;

- 5 % and 15 % by weight of the polymer mixture: a further portion of LLDPE having been made from fossil fuel.

- 5 % and 15 % by weight of the polymer mixture: the HDPE used as the second polymer.

[0057] This embodiment may have the advantage that an even higher portion of the carbon atoms of the fiber are derived from a renewable carbon source.

[0058] **Inventive blend 3:** According to one embodiment, the second polymer is a mixture of a first, bio-based HDPE and a second, petro-based HDPE. It has been observed that, although the physicochemical properties of bio- and petro-based HDPE differ from each other, also bio-based HDPE can be used - within the weight ranges described for embodiments of this invention - for producing artificial turf fibers having the desired properties.

[0059] Preferentially, the polymer mixture comprising 6-10% by weight of the polymer mixture and comprises 17-23% by weight of the second HDPE. It has been observed that this weight range of the bio-based and the petro-based HDPE provide for artificial turf fibers which are high in carbon derived from a renewable source and which at the same time have the desired physicochemical properties, in particular in respect to resilience, flexibility and resistance to mechanical stress.

[0060] **Inventive blend 4:** According to one embodiment, the totality of the first polymer is made from the renewable carbon source. Thus, there may be no need to add a further LLDPE polymer derived from fossil fuels.

[0061] The above mentioned polymer mixtures have been observed to provide for a polymer mixture that, after being molten and extruded for generating the artificial turf fiber from the extrusion product, provides PE fibers suitable for use as artificial turf fibers.

[0062] According to embodiments, the method comprises generating an artificial turf by incorporating the artificial turf fibers into a carrier.

[0063] According to embodiments, the first polymer is prepared from ethylene that was generated from the renewable carbon source.

[0064] According to embodiments, the renewable carbon source is biomass. For example, the biomass can be sugar cane.

[0065] According to embodiments, the method comprising selecting (i.e., choosing) the amount of the portion of the first polymer made from a renewable carbon source and optionally selecting (i.e., choosing) also the portion of the second polymer that is made from a renewable carbon source such that the resulting artificial turf fibers consist to at least 20 % of one or more polymers made from a renewable carbon source and/or such that the artificial turf to be generated from the fiber consists to at least 6% by its weight of one or more polymers made from a renewable carbon source.

[0066] For example, the fraction of biobased carbon content (BCC) can be determined via the amount of ^{14}C isotopes in a sample. Embodiments of the artificial turf fiber may comprise a sufficiently high fraction of BCC to be awarded, one, two or even more "stars" according to the classification schema of VINCOTTE, Doc Ref OK20, 2013.

[0067] In total, the bio-based carbon content of the generated artificial turf fiber may, for example, lie within a range of 7 and 86 % by weight of the polymer mixture. The mixing may be performed in an extruder.

[0068] According to embodiments, the polymer mixture is extruded into a monofilament. One or more of the monofilaments are formed into one of the artificial turf fibers. The method may comprise forming one or more of the monofilaments into one of the artificial turf fibers. According to some embodiments, the polymer mixture is extruded directly into a monofilament. The method comprises quenching the monofilament, reheating the monofilament, and stretching the reheated monofilament to form the monofilament into an artificial turf fiber.

[0069] Alternatively, the polymer mixture is extruded into a tape. The tape is sliced into stripes and one or more of the stripes are formed into one of the artificial turf fibers. Preferentially, the stripes are quenched, reheated and stretched before they are formed into artificial turf fibers.

[0070] Extruding the polymer mixture and quenching, reheating and stretching the extrusion product may be advantageous as said aspects may affect the physical properties of the monofilament or PE stripe used for generating the artificial turf fiber. For example, the stretching may trigger the generation of crystalline portions which may increase the surface roughness of a fiber and help to mechanically fix the fiber in the carrier, in particular if a liquid backing (e.g. latex or polyurethane) is added on the backside of the carrier such that the liquid backing wets the lower portions of the fiber and firmly includes the fiber after the solidification of the backing. Thus, the reheating and stretching steps may be used to "fine-tune" the properties of the artificial turf fibers to the requirements of a specific end-product.

[0071] The backing can be, for example, latex or a polyurethane (PU) based backing. The backing can be added as a liquid to the lower side of the carrier having incorporated the artificial turf fibers. The liquid backing wets the carrier and the lower parts of the incorporated fibers. Upon solidification, the backing strongly fixes the fibers in the backing.

[0072] In addition, or alternatively, a cohesive layer is applied between the fibers and the backing. In addition, or alternatively, the fibers are attached to the carrier or the backing by triggering a chemical reaction between the fibers and the carrier (or the backing).

[0073] For example, one or more of the monofilaments or stretched stripes may be bundled into an artificial turf fiber.

[0074] According to embodiments, the incorporation of the fibers into the carrier comprises:

- arranging the artificial turf fibers on the carrier, wherein first parts of one or more monofilaments of the arranged artificial turf fibers are exposed to a bottom side of the carrier and second parts of said monofilaments are exposed to a top side of the carrier;
- adding a fluid on the bottom side of the carrier such that at least the first parts become embedded in the fluid; and
- 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, the solid film acting as an artificial turf backing.

[0075] In a further aspect, the invention relates to an artificial turf fiber which consists at least partially of a polymer made from a renewable carbon source. The fiber comprises:

- a first polymer in an amount of at least 57% by weight of the fiber, wherein a portion of at least 30 % by weight of the first fiber is made from the renewable carbon source; and
- a second polymer in an amount of at least 8 % by weight of the fiber, the second polymer being HDPE.

[0076] According to embodiments, at least 20 % by weight of the artificial turf fiber are generated from a renewable carbon source. The artificial turf fiber is an extrusion product of a polymer mixture created according to a method of any one of the embodiments described herein.

[0077] In a further aspect, the invention relates to an artificial turf fiber comprising the ^{14}C isotope in an amount indicating that 20 % by weight of the polymer of the artificial turf fiber is made from a renewable carbon source.

[0078] In a further aspect, the invention relates to a piece of artificial turf. The method comprises a carrier, e.g. a mesh made of natural or synthetic yarn, and a plurality of artificial turf fibers described above which are incorporated into the carrier. The incorporation may be performed by tufting the fiber into the carrier. Alternatively, the incorporation of the fibers into the carrier comprises knitting or weaving the artificial turf fibers into the carrier. At least parts of the artificial turf fibers are embedded in a backing, e.g. by applying the backing in liquid form on the backside of the carrier comprising the tufted fibers. The backing solidifies and mechanically fixes said portions of the fibers in the backing. The backing may be made at least partially from a renewable carbon source.

[0079] Whether or not a polymer is biobased or petrobased or is a mixture of biobased and petrobased polymers can easily be determined via radiocarbon dating, e.g. according to the ASTM D6866 standard for determining the biobased content of solid, liquid, and gaseous samples.

[0080] The weight percentages specified herein relate to the pure polymer without additives. According to some embodiments, the polymer mixture further comprises additives such as pigments, flame retardants, nucleating agents, or the like. The additives are typically added as ingredients of a "master batch", i.e., a portion of e.g. 10% by weight of the polymer mixture comprising the additives. The polymer of the master batch is preferentially petro-based LLDPE, but may likewise be bio-LLDPE, petro-HDPE or bio-HDPE.

[0081] "Artificial turf" as used herein is a surface of synthetic fibers incorporated into a carrier, e.g. a woven textile or synthetic fabric. Artificial turf is commonly made to look like natural grass and is often used in arenas for sports that were originally or are normally played on grass. For example, the fibers may be tufted or otherwise fixed into the carrier and optionally a backing layer at the bottom side of the artificial turf. The fibers are, for example, monofilamented or twisted yarns of thermoplastic materials, mostly polyethylene. The carrier can be made, for example, of polypropylene. According to some embodiments, the fibers are fixed with an adhesive to the carrier. The adhesive can be, for example, a mixture of styrene-butadien-rubber (SBR) latices and fillers such as calcium carbonate. Alternatively, the adhesive can be a polyurethane-based adhesive.

[0082] A variety of different types of artificial turf exists: some systems essentially consist of a carrier, artificial turf fibers incorporated into the carrier and optionally a backing to better fix the fibers in the carrier. Other types of artificial turf systems comprise an additional infill layer on top of the carrier. The infill may consist of sand, granules of recycled rubber or other synthetic granules or a mixture thereof.

[0083] For example, artificial turfs can also be used as carpets placed onto a substructure of rubber granules acting as a shock damping layer. The carpet structure is filled with sand and rubber granules in order to keep the structure in place so that the carpet does not slip and the fibers stay in an upright position. The filling material is also referred to as infill or infill material. The infill can be, for example, SBR-rubber or EPDM-rubber, both elastomeric materials in irregularly granulated form. The SBR-rubber is commonly sourced from used tires.

[0084] A "polymer derived from renewable biomass", "bioplastic" or "bio-based polymer" is a polymer that is derived from renewable biomass sources, e.g. renewable plant materials, such as vegetable fats and oils, corn starch, or microbiota. Biopolymers can be made from agricultural byproducts using microorganisms. This means that the chemicals used for generating the polymer, e.g. PE, do not any longer originate from petroleum oil, but from renewable resources, in particular plants and other organisms that sequestrate CO_2 from the (current, not cambric) atmosphere via photosynthesis and bind it in the form of biomass. Accordingly, a polymer that is made from a renewable carbon source is also referred herein as "bio-based", "bio-", "green" or "renewable" polymer. Bio-LLDPE is also known as "renewable polyethylene", "bio-polyethylene", "green-PE" or "bio-PE"). Typically, it is polyethylene made out of ethanol, which becomes ethylene after a dehydration process.

[0085] By contrast, common plastics, such as fossil-fuel plastics (also called petro-based polymers), are derived from petroleum or natural gas. Production of such plastics tends to require more fossil fuels and to produce more greenhouse gases than the production of biobased polymers.

[0086] "Low-density polyethylene" (LDPE) is a thermoplastic made from the monomer ethylene having a density in the range of 0.910-0.940 g/cm^3. Embodiments of the invention are based on LDPE whose density range is within the above specified sub-range.

[0087] "Linear low-density polyethylene" (LLDPE) as used herein is a substantially linear polymer (polyethylene), with significant numbers of short branches. LLDPE differs structurally from conventional LDPE because of the absence or reduced number of long chain branching. The linearity of LLDPE results from the different manufacturing processes of LLDPE and LDPE. In general, LLDPE is produced at lower temperatures and pressures by copolymerization of ethylene and alpha-olefins with the aid of a catalyst system.

[0088] "High-density polyethylene" (HDPE) as used herein is a PE having a density of greater or equal to 0.941 g/cm^3. HDPE has a low degree of branching. The mostly linear molecules pack together well, so intermolecular forces are stronger than in highly branched polymers. HDPE can be produced by chromium/silica catalysts, Ziegler-Natta catalysts or metallocene catalysts; by choosing catalysts and reaction conditions, the smaller amount of branching that does occur can be controlled by adding alpha-olefins, acting as co-monomers. These catalysts prefer the formation of a transition state at the reacting ends of the growing polyethylene molecules. They cause new monomers to add to the ends of the molecules, rather than along the middle, causing the growth of a linear chain. HDPE has high tensile strength.

[0089] A "co-monomer" as used herein is a polymerizable precursor to a copolymer aside from the principal monomer. In some cases, only small amounts of a comonomer are employed, in other cases substantial amounts of co-monomers are used. Furthermore, in some cases, the co-monomers are heterogeneously incorporated within the polymer chain, whereas in other cases, they are homogeneously incorporated. The distribution of co-monomers is referred to as the chemical composition distribution of a copolymer.

[0090] A "polymer mixture" as used herein is a mixture of polymers with different compositions, capable of being differentiated by their physicochemical properties, also referred to as blend after extrusion melting. The melting process combines the individual and distinguishable components of the mixture homogeneously, such that a polymeric material is generated with specific capabilities.

Brief description of the drawings

[0091] In the following, embodiments of the invention are explained in greater detail, by way of example only, making reference to the following drawings:

Fig. 1	is a flow chart of a method for producing bio-PE based artificial turf.
Fig. 2	depicts a piece of artificial turf.
Fig. 3	depicts an LDPE, an LLDPE and a HDPE molecule.
Fig. 4	depicts a polymer mixture according to one embodiment "A".
Fig. 5	depicts a polymer mixture according to another embodiment "B".

Fig. 6 depicts a polymer mixture according to another embodiment "C".

Fig. 7 depicts the extrusion of the mixture into a monofilament.

[0092] **Fig. 1** is a flow chart of a method for producing bio-PE based artificial turf 200. In a first step 102, a polymer mixture 300, 400 is created by mixing at least a first polymer 304; {404; 406} and a second polymer 302; 402. The mixing may be performed in a separate container or directly in an extruder. The first polymer, e.g. a bio-LLDPE or a mixture of bio-LLDPE and petro-LLDPE, is added in an amount of at least 57% by weight of the polymer mixture and consists of polyethylene made from renewable biomass. The second polymer, e.g. petro-HDPE or bio-HDPE or a mixture thereof, is added in an amount of at least 8 % by weight of the polymer mixture. Optionally, additives may be added to the mixture, e.g. via a master-batch or as separate ingredients. The polymer mixture is heated above the melting point of the polymers to form a liquid polymer mixture. In a next step 104, the polymer mixture is extruded, e.g. into monofilaments or a film. The monofilaments or the film may be quenched, the film may be sliced into stripes, the monofilaments or stripes may be reheated and stretched and/or further processed for texturizing or curling the monofilaments or stripes. In a further step 106, the extrusion product is formed into artificial turf fibers, e.g. by bundling multiple monofilaments or stripes to a fiber. In step 108, the artificial turf fibers are incorporated into a carrier 204, e.g. by tufting or weaving the monofilaments into a woven fabric used as the carrier.

[0093] **Fig. 2** depicts a piece of artificial turf 200 that faithfully reproduces natural grass. A plurality of artificial turf fibers 202 having been generated from a polymer mixture comprising biobased PE and petrobased PE is incorporated into a carrier 204. For example, the fibers 202 can be tufted into the carrier 204 and be fixed at the bottom side of the carrier. The largest fiber portions 208 extend upward from the carrier. The carrier may be a mesh or a woven fabric made of synthetic or naturally occurring materials. For example, the carrier may be polypropylene. A backing 206 may be applied on the backside of the carrier to improve the fixing of the fibers in the carrier. For example, a liquid PU or latex mass can be applied that wets the portions 210 of the fibers 202 extending to the lower side of the carrier. When the mass has solidified, it tightly fixes the fibers in the carrier. Alternatively, or in addition, adhesive substances which glue the fibers to the carrier can be applied. The space above the carrier and between the upper portions 208 of the fibers can be filled with sand and rubber granules in order to keep the structure in place so that the artificial turf does not slip and the fibers stay in an upright position.

[0094] The production of a piece of artificial turf as depicted in Fig. 2 according to embodiments of the invention may comprise the following steps: 1. Extrusion of the polymer mixture into monofilaments (see Fig. 6); 2. Drawing and thermofixing of the filaments, e.g. by heating the portions of the fibers above or close to their melting temperature for a short period of time, e.g. some seconds; 3. Arranging multiple monofilaments such that they are aligned into bundles of monofilaments centered around a common axis; and optionally texturizing of the filaments. Texturizing means the transformation of the smooth and evenly stretched filaments into crimped and bent filaments. 4. Tufting of the monofilaments or bundles of monofilaments as artificial turf fiber onto the fabric, whereas tufting means the process of stitching the filaments or bundles through the fabric. This forms loops 210 of filaments or filament bundles which are cut through at the outward ends of the loops. Thereby, bunches of fibers extending orthogonally away from the carrier layer are formed. 5. Fixing the fibers at the backside of the fabric with an adhesive.

[0095] **Fig. 3** depicts a petrobased LDPE molecule 150, a petrobased LLDPE molecule 160 and a petrobased HDPE molecule 170.

[0096] (HDPE,) LDPE and LLDPE are generated by different polymerization processes. Depending on the polymerization process used for generating PE, the PE macromolecules are more or less side-chain branched. Side-chain branching means that the chain-like macromolecules comprise shorter or longer side branches extending from the main polymer chain. The degree of crystallinity depends strongly on the extent of side-chain branching. HDPE and LLDPE may be generated in the same process (swing reactor technique).

LLDPE Generation

[0097] Conventionally produced, petrobased LLDPE is a substantially linear PE polymer with significant numbers of short branches, commonly made by copolymerization of ethylene with longer chain olefins. LLDPE differs structurally from conventional LDPE because of the absence of long chain branching. It has turned out that petrobased LLDPE generated in a polymerization process that uses ethylene and a co-monomer is very much appropriate for an outbalanced ratio between softness and rigidity of artificial turf fibers. In LLDPE polymers, the ability of the macromolecules to crystallize is sterically hindered by the side chains introduced by the co-monomers.

[0098] LLDPE has higher tensile strength and higher impact and puncture resistance than does LDPE. It is very flexible and elongates under stress. It can be used to make thinner films, with better environmental stress cracking resistance. It has good resistance to chemicals. It has good electrical properties.

[0099] However, it is not as easy to process as LDPE, has lower gloss, and narrower range for heat sealing. LLDPE is less shear sensitive because of its narrower molecular weight distribution and shorter chain branching. During a shearing process, such as extrusion, LLDPE remains more viscous and, therefore, harder to process than an LDPE of equivalent melt index. The lower shear sensitivity of LLDPE allows for a faster stress relaxation of the polymer chains during extrusion, and, therefore, the physical properties are susceptible to changes in drawing ratios. Upon applying and increasing a deformation force on a PE fiber, i.e., in case of an increasing deformation rate, LLDPE does not show an increase in viscosity because of the lack of long-chain branching in LLDPE allows the chains to slide by one another upon elongation without becoming entangled. Thus, the rheological properties of LLDPE are summarized as "stiff in shear" and "soft in extension".

[0100] The linearity of LLDPE results from the different manufacturing processes of LLDPE and LDPE. In general, LLDPE is produced at lower temperatures and pressures by copolymerization of ethylene (acting as monomer) and co-monomers such as higher alpha-olefins (e.g. 1-butene, 1-hexene, or 1-octene). Polymerization of 1-olefins or α-olefins together with ethylene results in LLDPE polymers referred to as "PE co-polymers". The copolymerization process produces a petrobased LLDPE polymer that has a narrower molecular weight distribution than petrobased LDPE and in combination with the linear structure, significantly different rheological properties. The ethylene monomers form the main polymer chain. When a co-monomer is added to the main polymer chain, a side-chain branch is formed at that position of the chain. Thus, the length, the number and the distribution of side-chain branches can be determined by the type and amount of co-monomer used in the co-polymerization process. Number, length and distribution (along the backbone of the macromolecules) of the co-monomers determine the degree of crystallinity and thereby the mechanical properties of the produced polymer.

[0101] LLDPE is prepared in a low pressure process (slurry/solution/gas-phase) by using metallocene transition metal catalysts, Ziegler/Natta-type catalysts or Phillips type of catalysts. Ziegler and Phillips (multi-site) catalysts produce polymers with relatively broad molecular weight distributions and in case of co-polymers a relatively broad co-monomer distribution. Metallocene (single site) catalysts produce polymers with narrow molecular weight distribution and homogeneous co-monomer distribution. The actual polymerization process can be done either in slurry, solution phase or in gas phase reactors.

HDPE Generation

[0102] HDPE has less side branches than LDPE. In HDPE, the degree of crystallinity can reach 80 %. HDPE can be produced by chromium/silica Phillips catalysts, Ziegler-Natta catalysts or metallocene catalysts; by choosing catalysts, reaction conditions and co-monomer concentration, the small amount of branching that does occur can be controlled. These catalysts prefer the formation of a transition state at the reactive ends of the growing polyethylene molecules. They cause new monomers to add to the ends of the molecules, rather than along the middle, causing the growth of a linear chain. HDPE has high tensile strength.

LDPE Generation

[0103] LDPE demonstrates a dramatic rise in viscosity because of chain entanglement upon applying and increasing a deformation force on a PE fiber, i.e., in case of an increasing deformation rate. LDPE is prepared in a high pressure process using a radical initiator. It is not created in a polymerization reaction using co-monomers. The radical polymerization process used to make LDPE does not include a catalyst that "supervises" the radical sites on the growing PE chains. (In HDPE synthesis, the radical sites are at the ends of the PE chains, because the catalyst stabilizes their formation at the ends.) Secondary radicals (in the middle of a chain) are more stable than primary radicals (at the end of the chain), and tertiary radicals (at a branch point) are more stable yet. Each time an ethylene monomer is added, it creates a primary radical, but often these will rearrange to form more stable secondary or tertiary radicals. Addition of ethylene monomers to the secondary or tertiary sites creates branching.

Bio- and petro-based LLDPE Generation

[0104] Currently, only a very limited number of biobased LLDPE types are available on the market. For example, a bio-based Ziegler/Natta catalyzed gas-phase polymerized LLDPE is available which is generated from mixture of polymerization educts comprising ethylene and 1-butene co-monomer or ethylene and 1-hexene co-monomer. The polymerization reaction to generate the biobased LLDPE from said reaction mixture is performed in a Spherilene-process. The resulting bio-based LLDPE polymer has a (presumably bimodal) molecular weight distribution and other physico-chemical properties which differ significantly from that of the available petrobased LLDPE molecules which are generated in a solution based polymerization process.

[0105] It has been observed that the available biobased LLDPE cannot be used for generating artificial turf fibers which essentially consist of said biobased LLDPE type alone. This is because the resulting fiber is far too soft.

[0106] It has also been observed that the available biobased LLDPE cannot be used for simply replacing petrobased LLDPE having hitherto been used as a component in mixed-PE-type artificial turf fibers as the physicochemical properties of the bio-based LLDPE are very different from the properties of the petro-based LLDPEs on the market. For example, a petro-based LLDPE sometimes used for producing artificial turf fibers is a Ziegler/Natta catalyzed solution polymerized LLDPE, whereby the mixture of polymerization educts comprise ethylene and 1-octene co-monomers in an amount of around 10 % by weight of the polymerization mixture. Replacing the petro-based with an identical amount of the bio-based LLDPE will not result in a polymer mixture that is suitable for producing artificial turf fibers as the physicochemical properties and, moreover, the processability of the bio-based LLDPE are very different from the properties of the petro-based LLDPE.

[0107] In the following, polymer mixtures comprising a first polymer derived from a renewable polymer source and a second polymer typically derived from fossil fuels are described which are particularly suited for generating artificial turf fibers which are soft, flexible and at the same time sufficiently rigid.

[0108] **Fig. 4** depicts a polymer mixture 300 according to one embodiment "A". The polymer mixture essentially consists of a first polymer consisting of bio-LLDPE 304 and a second polymer consisting of petro-HDPE 304. In fact, a portion of the first polymer may be added separately in the form of a bio-LLDPE-based master batch. All components of mixture A are added to an extruder, homogeneously mixed, and heated above their melt temperatures to form a homogeneous, liquid polymer mass. The first polymer is a bio-LLDPE 304 having a density of 0,918 g/ml and a melt flow rate of 2 to 4 g/10 min. The second polymer is a HDPE 302 having a density of 0,955 g/ml and a melt flow rate of 3 to 5 g/10 min. At least 57 % by weight of the polymer mixture, in this case: 75 %, consist of the first polymer, at least 8 %, in this case 25 %, by weight of the polymer mixture consist of the second polymer (petro-HDPE). In case the polymer mixture further comprises some additives (typically in the range of less than 5 % by weight of the polymer mixture), the fraction of the first and second polymers may be altered accordingly. The liquid polymer mixture is extruded into a monofilament as depicted in Fig. 7.

[0109] Thus, in the depicted example, more than 70% of the PE fiber mass (which typically constitutes the largest portion of the mass of a piece of artificial turf) is made from renewable raw materials. The polymer mixture has been observed to provide artificial turf fibers being both sufficiently flexible as well as sufficiently rigid for being used as artificial turf fibers.

[0110] **Fig. 5** depicts a polymer mixture 400 according to another embodiment. The polymer mixture comprises bio-LLDPE 404 having a density of 0.916 to 0.920 g/ml and a melt flow rate of 2 to 4 g/10 min at 190 °C / 2.16 kg. The second polymer 402 is in fact a mixture of a petro-HDPE 408 having a density of 0,955 g/ml and a melt flow rate of 3 to 5 g/10 min and a bio-HDPE 406 having a density of 0.948 to 0.959 g/ml (e.g. 0,954 g/ml) and a melt flow rate of 4 to 5 g/10 min. Both the LLDPE 404 and the HDPE 406 are made from renewable carbon source. For example, the LLDPE 404 may constitute 72 % of the weight of the polymer mixture, the bio-HDPE 406 may constitute 20 % of the weight of the polymer mixture and the petro-HDPE 408 may constitute 8% of the mixture. Thus, in the depicted example, more than 90% of the PE fiber mass is made from renewable raw materials.

[0111] By increasing the fraction of bio-LLDPE and/or bio-HDPE within the above specified ranges, up to 97 % by weight of the polymer mixture can be made of renewable "bio-PE" (the remaining 3% relating to petro-based HDPE and additives).

[0112] **Fig. 6** depicts a polymer mixture 500 according to a further embodiment. According to this embodiment, the second polymer 502 may be completely petrol based (as shown), completely bio-based or may be a mixture of bio- and petro-based HDPE. The first polymer is a mixture of a bio-LLDPE having a density of 0,917 g/ml and a melt flow rate of 2 to 4 g/10 min and a petro-LLDPE 406 having a density of 0.915 to 0.919 g/ml and a melt flow rate of 2 to 4 g/10 min at 190 °C / 2.16 kg. By choosing a desired ratio of bio- and petro-based LLDPE, the weight fraction of the artificial turf fiber that is derived from a renewable carbon source may be chosen freely, e.g. 33 %.

[0113] Polymer mixtures 300, 400, 500 have all been observed to provide artificial turf fibers being both sufficiently flexible as well as sufficiently rigid for being used as artificial turf fibers. Based on said amounts and characteristics of the first and second polymers, 8 to 97 % by weight of the polymer mixture can be made of renewable "bio-PE".

[0114] According to embodiments, the creation of the polymer mixture comprises mixing the first and the second polymer in an extruder. This may be advantageous as no additional container or process step for mixing the first and second polymers is necessary. Rather, both the first and the second polymer can be fed as polymer granules into the extruder. In the extruder, the polymer granules are mixed and heated to form a liquid polymer mass that is extruded to a plurality of holes in an extrusion plate.

Further Examples (not shown)

[0115] The following inventive blends are exemplarily described to make clear what is given in the embodiments. Compositions and type of polymers are not limiting the invention. Other types of polymers and different compositions may result in comparable blends and hence in filaments with comparable properties.

Inventive blends and comparative blend

[0116] Two inventive blends and one comparative blend are prepared from commercially available polymers. The blends are extruded and further processed into monofilaments. The monofilaments are used for the fabrication of artificial turf surfaces. The components for the blends are listed in the following table:

Polymer type	Co-monomer	Density [kg/m^3]	MI [g/10 min]
Bio-LLDPE	1-hexene	918	2.7
Petro-HDPE	1-octene	955	4.0
Petro-LLDPE	1-octene	917	2.3

[0117] The nominal values for the melt flow rate are measured at 190 °C and 2.16 kg load.

[0118] Petro-LLDPE is used for the preparation of the master-batch. The master-batch consists of the following main components:

Polymers 66.5 %wt.
Pigments 18.1 %wt.
Additives 15.4 %wt.

[0119] The master-batch is prepared on a 40 D co-rotating twin screw extruder. The specific proportions of polymers, pigments and additives are fed by gravimetric dosing into the hopper of the extruder, extruder-blended and pelletized.

Blend compositions

[0120] The inventive blends 1 and 2 consist of a first polymer A, a second polymer B and master-batch. The comparative blend consists of a first polymer C, a second polymer B and master-batch. The components are extruder-blended in the course of the filament production. The compositions of polymers and master-batch are given in the table below:

	Inventive blend B1	Inventive blend B2	Comparative blend CB
Bio-LLDPE	69.5 % wt.	79.5 % wt.	-
Petro-LLDPE	-	-	79.5 % wt.
Petro-HDPE	20 % wt.	10 % wt.	10 % wt.
Master-batch of Petro-LLDPE	10 % wt.	10 % wt.	10 % wt.
Processing aid (e.g. fluoroelastomer)	0.5 % wt.	0.5 % wt.	0.5 % wt.

[0121] The fibers are produced by extrusion on an extruder. The blend components, i. e. the first polymer, the second polymer, the master-batch and the processing aid are fed via gravimetric dosing into the extruder. The single-screw extruder is equipped with a melt pump, melt filtration and a circular die face with 165 spinnerets. The temperature setting of the extruder is given in the next table.

	zone 1	zone 2	zone 3-5	flange	filtration zones	melt pump 1	melt pump 2	dies
°C	190	210	230	230	230	230	230	230

[0122] The die face is located above a water-bath at a distance of 40 mm from the water surface. The water temperature is kept within 30±0,5 °C. The fibers are dried and heated on a first set of godets up to 80 °C. The fibers are passed through a hot air oven to a next set of godets heated up to 90 °C. The temperature of the first hot airheating zone is maintained at 90 °C. The first and the second pair of godets run at differential speed, such that the fibers are stretched at a ratio between 1:5 and 1:6, preferably at a ratio of 1:5.6. In the next 2 hot air ovens the fibers are annealed at temperatures of 115 °C and draw ratios of 0.9 and 0.97. In the last section the fibers are cooled on godets to 20 °C. The fibers are transferred to bobbin winders or texturizer units.

Properties of the filaments

[0123] The properties of the filaments were determined by common test methods. Specimens of monofilaments from different polymer blends were sampled after production of the filaments. For the abrasion test the filaments were tufted onto a carrier fabric and the carpets were bed coated by applying SBR-latex to the backside of the carpet and passing through a hot-air oven at a temperature of 85 °C. Tufting, coating and drying were comparable for all samples with different filament composition.

[0124] The test results are given in the following table:

	Test Parameter	**Method**	**Unit**	**B1**	**B2**	**CB**
1	Fibre thickness	internal	μm	108	111	115
2	Fibre width	internal	mm	1,265	1,354	1,382
3	Fibre weight	EN 15330-1	dtex	1002	980	934
4	**Shrinkage**	**5 min / 90 °C**	**%**	**3**	**4**	**4**
5	Curl	5 min / 85 °C		no curl	no curl	no curl
6	**Tensile strength**	**EN 13864**	**N**	**12,3**	**11,1**	**11,4**
7	Elongation at break	EN 13864	%	66	65	70
8	Resistance to artificial weathering / UV-A	EN 14836				
8.1	**Tensile strength**	**EN 13864**	**N**	**12,2 (= -1 %)**	**10,9 (=-2 %)**	**10,8 (= -5 %)**
8.2	Color change	EN 20105-A02	GM	4-5	4-5	4
8.3	Weight loss	internal	%	6	6	6
9	Abrasion resistance	EN 13672	%	0,104	0,109	0,113
10	DSC peak temperature	ISO 11357-3	°C	129,95	128,45	126,05
11	Crystallinity (DSC)		%	38.5	38.1	40.5
12	Biobased carbon content	ASTM D6866	%	61	71	0

[0125] As can be inferred from the above table, the properties of artificial turf fibers made from inventive blends B1 and B2 are similar, sometimes even better than the comparative blend although a significant portion of bio-LLDPE was used for generating the fibers. In particular, properties relating to resistance to artificial weathering, tensile strength, color change show that bio-based artificial turf fibers can be produced which fulfill the same quality criteria like conventional petro-based fibers. In particular, no curling was observed also for the bio-based fibers, and the abrasion resistance is almost as high as that of the comparative blend.

Test methods

Density

[0126] The density is measured according to ASTM. The data were taken from the technical data sheets of the suppliers.

Melt flow index

[0127] The density is measured according to ASTM. The data were taken from the technical data sheets of the suppliers.

Fiber dimensions

[0128] Fiber dimensions relate to the cross section of the fibers. The fibers are clamped and cut near the clamp. Length and thickness are determined under a microscope.

Fiber weight

[0129] The weight (in dtex) is determined by weighing a sample of 10,000 meters in length.

Tensile strength and elongation at break

[0130] The tests are carried out on a Zwick/Roell Z 1.0 tensile testing equipment. Tensile strength and elongation at break are taken from the stress/strain records.

Artificial weathering

[0131] Artificial weathering is tested by using a UV-A cabinet and exposing the fiber specimens for 3.000 h. Afterwards the tensile strength is measured using a tensile tester. The discoloration of the fiber is visually assessed.

Abrasion resistance

[0132] Abrasion resistance was measured by Taber test according to EN 13672. 5000 Cycles with an H 18 rotatory abraser are done and the weight loss of the samples is measured.

DSC

[0133] Differential scanning calorimetry measurements are carried out on a Perkin Elmer DSC 6 instrument or a Mettler-Toledo DSC 823^e instrument. A first heating run is performed with a heating rate of 10 °C/min from room temperature to 160 °C. The samples are held isothermal at 160 °C for 3 minutes and then cooled down with a cooling rate of 10 °C/min. to room temperature. A second heating run is taken for examination of the maximum peak temperature. The crystallinity is calculated by determining the heat of fusion by integration of the second heat run and using the following equation:

$$\text{Crystallinity (\%)} = (H_f/293\ \text{J/g}) * 100\ (H_f \text{ in J/g})$$

Shrinkage, curling, degree of texturization

[0134] The shrinkage of monofilaments and texturized yarn is measured by thermal treatment of 1 meter of a sample in a circulating air oven at 90 °C for 5 minutes. The length of the samples before and after thermal treatment is determined and calculated in % shrinkage. The curl is measured by winding up approximately 1 meter of filament to a bundle, fixing one end with a strap and cutting the opposite end, such that a bunch forms. The bunch is heated at 85 °C for 5 minutes. The samples are visually assessed whether or not curling can be detected.

Bio-based carbon content

[0135] The bio-based carbon content is determined by ^{14}C radiocarbon method, according to ASTM D 6866. ^{14}C is the unstable isotope of carbon. As long as living organisms are in exchange with the biosphere they digest carbon and with it ^{14}C-isotopes. As the ^{14}C-content is stationary in the atmosphere the amount of that isotope does not change in the biomass. In dead biomass the amount of ^{14}C begins to decrease by radioactive decay. The content of this isotope is depleting over time. Fossil carbon material has a lower content of ^{14}C isotopes than younger carbon material. By that difference, the ratio between bio-based (younger) and petro-based (fossil) carbon can be measured with mass spectrometric isotope analysis.

[0136] **Fig. 7** depicts the extrusion of a polymer mixture into a monofilament 606. The polymer mixture can be a mixture 300, 400 as depicted, for example, in Figures 4 and 5 or according to any other embodiment described herein. The heated, liquid polymer mixture contained in an extruder 604 wherein the first and second polymers are mixed is pressed through a hole 608 of an extrusion plate 602. The extrusion product, in this case, a monofilament 606, is quenched in a quenching solution, e.g. a water bath having about 20°C to allow the monofilament to solidify. Then, the monofilament is reheated, e.g. to a temperature of about 70°C, and stretched, e.g. by a factor of 1.5 to 5. The stretching process boosts the generation of crystal structures in the monofilament and thus increases the surface roughness of the monofilament (not shown). The monofilament may optionally be bundled with further monofilaments to form an artificial turf fiber. The fiber is incorporated into a carrier material to form a piece of artificial turf as depicted in Fig. 2.

List of reference numerals

[0137]

102-108	steps
150	LDPE molecule
160	LLDPE molecule
170	HDPE molecule
200	artificial turf
202	artificial turf fibers
204	carrier
206	backing
208	first parts of fibers fiber
210	second parts of fibers incorporated into the backing
300	polymer mixture
302	second polymer: HDPE, petrobased
304	first polymer: LLDPE, biobased
402	second polymer: HDPE mixture;
404	first polymer: LLDPE, biobased
406	second polymer component I: HDPE, biobased
408	second polymer component II: HDPE, petrobased
502	second polymer: HDPE, petrobased;
504	first polymer: LLDPE mixture
506	first polymer component I: LLDPE, biobased
508	first polymer component II: LLDPE, petrobased
602	extrusion plate
604	liquid polymer mixture in extruder
606	monofilament
608	hole in extrusion plate

Claims

1. A method of manufacturing artificial turf fibers which consist at least partially of a polymer made from a renewable carbon source, the method comprising:

    - creating (102) a polymer mixture (300, 400, 500) comprising

        • a first polymer (304; 404;504) in an amount of at least 57% by weight of the polymer mixture, wherein a portion (304, 404, 506) of at least 30 % by weight of the first polymer is made from the renewable carbon source; and
        • a second polymer (302; 402, 502) in an amount of at least 8 % by weight of the polymer mixture, the second polymer being HDPE;

    - extruding (104) the polymer mixture;
    - generating (106) the artificial turf fibers (202) from the extruded polymer mixture.

2. The method of claim 1, the first polymer being a linear low density polyethylene LLDPE.

3. The method of any one of the previous claim, the portion (304, 404, 506) of the first polymer being made from the renewable carbon source being a Ziegler/Natta catalyzed, gas-phase polymerized LLDPE generated from mixtures of polymerization educts, the polymerization educts comprising ethylene as the main monomer and a co-monomer, the co-monomer being 1-butene and/or 1-hexene.

4. The method of claim 3, the portion (304, 404, 506) of the first polymer being made from the renewable carbon source being a linear low density polyethylene LLDPE having a density of 0.916 to 0.920 g/ml and a melt flow rate of 2 to 4 g/10 min.

5. The method of any one of the previous claim, the first polymer comprising a further portion (508) consisting of LLDPE made from fossil fuels, the further portion being a Ziegler/Natta catalyzed, solution polymerized LLDPE generated from mixtures of polymerization educts, the polymerization educts comprising ethylene as the monomer and a co-monomer, the co-monomer being 1-octene.

6. The method of claim 5, the further portion (508) consisting of LLDPE made from fossil fuels and

- having a density of 0.930 to 0.940 g/ml and a melt flow rate of 2.5 to 5.5 g/10 min at 190 °C /2.16kg; or
- having a density of 0.915 to 0.919 g/ml and a melt flow rate of 2 to 4 g/10 min at 190 °C / 2.16 kg.

7. The method of any one of the previous claims, the second polymer (302, 402, 502) being a Ziegler/Natta catalyzed, solution polymerized HDPE generated from mixtures of polymerization educts, the polymerization educts comprising ethylene as the main monomer and a co-monomer, the co-monomer being 1-octene.

8. The method of claim 7, the second polymer (302, 402, 502) being HDPE having a density of 0.952 to 0.955 g/ml and a melt flow rate of 3 to 5 g/10 min.

9. The method of claim 7 or 8, the second polymer being a HDPE made from fossil fuels.

10. The method of any one of the previous claims, the second polymer being a Ziegler/Natta catalyzed, gas-phase polymerized HDPE generated from mixtures of polymerization educts, the polymerization educts comprising ethylene as the main monomer and a co-monomer, the co-monomer being 1-butene.

11. The method of claim 10, the second polymer (302, 402, 502) being a HDPE having a density of 0.948 to 0.962 g/ml and a melt flow rate of 0.2 to 20 g/10 min at 190 °C / 2.16 kg, and more preferentially having a density of 0.948 to 0.959 g/ml and a melt flow rate of 4 to 5 g/10 min.

12. The method of claim 11, the second polymer (302, 402, 502) being a HDPE made from a renewable carbon source.

13. The method of any one of the previous claims, the portion (304, 404, 506) of the first polymer being made from the renewable carbon source being within a range of 57 % and 87 % by weight of the polymer mixture, the amount of the second polymer being within a range of 8 % and 33 % by weight of the polymer mixture.

14. The method of claim 13,

- the portion (304, 404, 506) of the first polymer being made from the renewable carbon source being within a range of 65 % and 75 % by weight of the polymer mixture,
- a further portion (508) of the first polymer being LLDPE having been made from fossil fuel and being within a range of 5 % and 15 % by weight of the polymer mixture, and
- the amount of the second polymer being within a range of 15 % and 25 % by weight of the polymer mixture.

15. The method of claim 13,

- the portion (304, 404, 506) of the first polymer having been made from the renewable carbon source being within a range of 75 % and 87 % by weight of the polymer mixture,
- a further portion (508) of the first polymer being LLDPE having been made from fossil fuel and being within a range of 5 % and 15 % by weight of the polymer mixture, and
- the amount of the second polymer being within a range of 5 % and 15 % by weight of the polymer mixture.

16. The method of any one of the previous claims, the second polymer (302, 402, 502) being a mixture of a first HDPE (406) according to claim 10, 11 or 12 and a second HDPE (408) according to claim 7, 8 or 9.

17. The method of claim 16, the polymer mixture (400) comprising 6-10% by weight of the first HDPE and comprising 17-23% by weight of the second HDPE.

18. The method of any one of the previous claims 1-13, 16 and 17, the totality of the first polymer being made from the renewable carbon source.

19. The method of any one of the previous claims, further comprising generating an artificial turf (200) by incorporating (108) the artificial turf fibers into a carrier (204).

20. The method of any one of the previous claims, the first polymer being prepared from ethylene that was generated from the renewable carbon source.

21. The method of any one of the previous claims, the renewable carbon source being biomass.

22. The method of any one of the previous claims, the method comprising selecting the amount of the portion of the first polymer made from a renewable carbon source and optionally selecting also the portion of the second polymer that is made from a renewable carbon source such that the resulting artificial turf fibers consist to at least 20% of one or more polymers made from a renewable carbon source and/or such that the artificial turf to be generated from the fiber consists to at least 6% by its weight of one or more polymers made from a renewable carbon source.

23. The method of any one of the previous claims,

- wherein the polymer mixture is extruded into a monofilament, the method further comprising forming one or more of the monofilaments into one of the artificial turf fibers; or
- wherein the polymer mixture is extruded into a tape, the method further comprising: slicing the tape into stripes and forming one or more of the stripes into one of the artificial turf fibers.

24. The method of any one of the previous claims, the incorporation of the fibers into the carrier comprising:

- arranging the artificial turf fibers on the carrier, wherein first parts (210) of one or more monofilaments of the arranged artificial turf fibers are exposed to a bottom side of the carrier and second parts of said monofilaments are exposed to a top side of the carrier;
- adding a fluid on the bottom side of the carrier such that at least the first parts become embedded in the fluid; and
- 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, the solid film acting as an artificial turf backing (206).

25. An artificial turf fiber which consists at least partially of a polymer made from a renewable carbon source, the fiber comprising:

- a first polymer (304; 404;504) in an amount of at least 57% by weight of the fiber, wherein a portion (304, 404, 506) of at least 30 % by weight of the first fiber is made from the renewable carbon source; and
- a second polymer (302; 402, 502) in an amount of at least 8 % by weight of the fiber, the second polymer being HDPE.

26. The artificial turf fiber of claim 25, wherein at least 20% by weight of the artificial turf fiber are generated from a renewable carbon source, the artificial turf fiber being an extrusion product of a polymer mixture created according to a method of any one of claims 1-24.

27. An artificial turf fiber made of a polymer mixture, the artificial turf fiber comprising the ^{14}C isotope in an amount indicating that 20% by weight of the polymer of the artificial turf fiber is made from a renewable carbon source.

28. A piece of artificial turf (200) comprising:

- a carrier (204);
- a plurality of artificial turf fibers (202) of claim 25, 26 or 27 incorporated into the carrier (204), wherein parts of the artificial turf fibers are embedded in a backing (206) made at least partially from a renewable carbon source.

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

1. A method of manufacturing artificial turf fibers which consist at least partially of a polymer made from a renewable carbon source, the method comprising:

- creating (102) a polymer mixture (300, 400, 500) comprising

- a first polymer (304; 404;504) in an amount of at least 57% by weight of the polymer mixture, wherein a portion (304, 404, 506) of at least 30 % by weight of the first polymer is made from the renewable carbon source, the portion (304, 404, 506) of the first polymer being made from the renewable carbon source being a Ziegler/Natta catalyzed, gas-phase polymerized LLDPE generated from mixtures of polymerization educts, the polymerization educts comprising ethylene as the main monomer and a co-monomer, the co-monomer being 1-butene and/or 1-hexene; and
- a second polymer (302; 402, 502) in an amount of at least 8 % by weight of the polymer mixture, the second polymer being HDPE;

- extruding (104) the polymer mixture;
- generating (106) the artificial turf fibers (202) from the extruded polymer mixture.

2. The method of claim 1, the first polymer being a linear low density polyethylene LLDPE.

3. The method of any one of the previous claims, the portion (304, 404, 506) of the first polymer being made from the renewable carbon source being a linear low density polyethylene LLDPE having a density of 0.916 to 0.920 g/ml and a melt flow rate of 2 to 4 g/10 min at 190 °C / 2.16 kg.

4. The method of any one of the previous claim, the first polymer comprising a further portion (508) consisting of LLDPE made from fossil fuels, the further portion being a Ziegler/Natta catalyzed, solution polymerized LLDPE generated from mixtures of polymerization educts, the polymerization educts comprising ethylene as the monomer and a co-monomer, the co-monomer being 1-octene.

5. The method of claim 4, the further portion (508) consisting of LLDPE made from fossil fuels and

- having a density of 0.930 to 0.940 g/ml and a melt flow rate of 2.5 to 5.5 g/10 min at 190°C / 2.16 kg; or
- having a density of 0.915 to 0.919 g/ml and a melt flow rate of 2 to 4 g/10 min at 190 °C/2.16 kg.

6. The method of any one of the previous claims, the second polymer (302, 402, 502) being a Ziegler/Natta catalyzed, solution polymerized HDPE generated from mixtures of polymerization educts, the polymerization educts comprising ethylene as the main monomer and a co-monomer, the co-monomer being 1-octene.

7. The method of claim 6, the second polymer (302, 402, 502) being HDPE having a density of 0.952 to 0.955 g/ml and a melt flow rate of 3 to 5 g/10 min at 190 °C/2.16 kg.

8. The method of claim 6 or 7, the second polymer being a HDPE made from fossil fuels.

9. The method of any one of the previous claims, the second polymer being a Ziegler/Natta catalyzed, gas-phase polymerized HDPE generated from mixtures of polymerization educts, the polymerization educts comprising ethylene as the main monomer and a co-monomer, the co-monomer being 1-butene.

10. The method of claim 9, the second polymer (302, 402, 502) being a HDPE having a density of 0.948 to 0.962 g/ml and a melt flow rate of 0.2 to 20 g/10 min at 190 °C / 2.16 kg, and more preferentially having a density of 0.948 to 0.959 g/ml and a melt flow rate of 4 to 5 g/10 min at 190 °C / 2.16 kg.

11. The method of claim 10, the second polymer (302, 402, 502) being a HDPE made from a renewable carbon source.

12. The method of any one of the previous claims, the portion (304, 404, 506) of the first polymer being made from the renewable carbon source being within a range of 57 % and 87 % by weight of the polymer mixture, the amount of the second polymer being within a range of 8 % and 33 % by weight of the polymer mixture.

13. The method of claim 12,

- the portion (304, 404, 506) of the first polymer being made from the renewable carbon source being within a range of 65 % and 75 % by weight of the polymer mixture,
- a further portion (508) of the first polymer being LLDPE having been made from fossil fuel and being within a range of 5 % and 15 % by weight of the polymer mixture, and
- the amount of the second polymer being within a range of 15 % and 25 % by weight of the polymer mixture.

14. The method of claim 12,

- the portion (304, 404, 506) of the first polymer having been made from the renewable carbon source being within a range of 75 % and 87 % by weight of the polymer mixture,
- a further portion (508) of the first polymer being LLDPE having been made from fossil fuel and being within a range of 5 % and 15 % by weight of the polymer mixture, and
- the amount of the second polymer being within a range of 5 % and 15 % by weight of the polymer mixture.

15. The method of any one of the previous claims, the second polymer (302, 402, 502) being a mixture of a first HDPE (406) according to claim 9, 10 or 11 and a second HDPE (408) according to claim 6, 7 or 8.

16. The method of claim 15, the polymer mixture (400) comprising 6-10% by weight of the first HDPE and comprising 17-23% by weight of the second HDPE.

17. The method of any one of the previous claims 1-12, 15 and 16, the totality of the first polymer being made from the renewable carbon source.

18. The method of any one of the previous claims, further comprising generating an artificial turf (200) by incorporating (108) the artificial turf fibers into a carrier (204).

19. The method of any one of the previous claims, the first polymer being prepared from ethylene that was generated from the renewable carbon source.

20. The method of any one of the previous claims, the renewable carbon source being biomass.

21. The method of any one of the previous claims, the method comprising selecting the amount of the portion of the first polymer made from a renewable carbon source and optionally selecting also the portion of the second polymer that is made from a renewable carbon source such that the resulting artificial turf fibers consist to at least 20% of one or more polymers made from a renewable carbon source and/or such that the artificial turf to be generated from the fiber consists to at least 6% by its weight of one or more polymers made from a renewable carbon source.

22. The method of any one of the previous claims,

- wherein the polymer mixture is extruded into a monofilament, the method further comprising forming one or more of the monofilaments into one of the artificial turf fibers; or
- wherein the polymer mixture is extruded into a tape, the method further comprising: slicing the tape into stripes and forming one or more of the stripes into one of the artificial turf fibers.

23. The method of any one of the previous claims, the incorporation of the fibers into the carrier comprising:

- arranging the artificial turf fibers on the carrier, wherein first parts (210) of one or more monofilaments of the arranged artificial turf fibers are exposed to a bottom side of the carrier and second parts of said monofilaments are exposed to a top side of the carrier;
- adding a fluid on the bottom side of the carrier such that at least the first parts become embedded in the fluid; and
- 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, the solid film acting as an artificial turf backing (206).

24. An artificial turf fiber which consists at least partially of a polymer made from a renewable carbon source, the fiber comprising:

- a first polymer (304; 404;504) in an amount of at least 57% by weight of the fiber, wherein a portion (304, 404, 506) of at least 30 % by weight of the first fiber is made from the renewable carbon source, the portion (304, 404, 506) of the first polymer being made from the renewable carbon source being a Ziegler/Natta catalyzed, gas-phase polymerized LLDPE generated from mixtures of polymerization educts, the polymerization educts comprising ethylene as the main monomer and a co-monomer, the co-monomer being 1-butene and/or 1-hexene; and
- a second polymer (302; 402, 502) in an amount of at least 8 % by weight of the fiber, the second polymer being HDPE.

25. The artificial turf fiber of claim 24, wherein at least 20% by weight of the artificial turf fiber are generated from a renewable carbon source, the artificial turf fiber being an extrusion product of a polymer mixture created according to a method of any one of claims 1-23.

26. An artificial turf fiber made of a polymer mixture, the artificial turf fiber comprising the ^{14}C isotope in an amount indicating that 20% by weight of the polymer of the artificial turf fiber is made from a renewable carbon source.

27. A piece of artificial turf (200) comprising:

- a carrier (204);
- a plurality of artificial turf fibers (202) of claim 24, 25 or 26 incorporated into the carrier (204), wherein parts of the artificial turf fibers are embedded in a backing (206) made at least partially from a renewable carbon source.

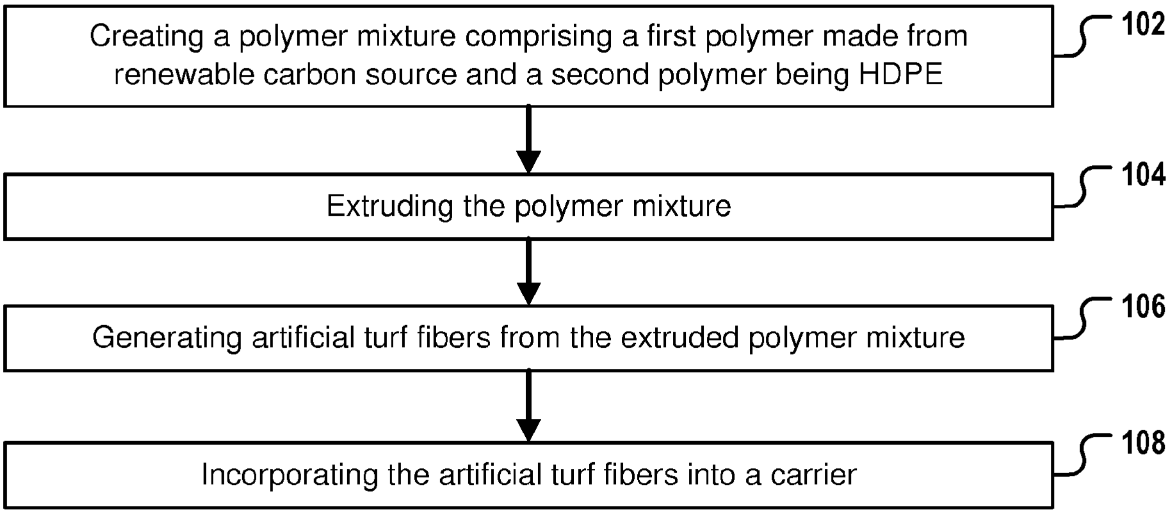

Creating a polymer mixture comprising a first polymer made from renewable carbon source and a second polymer being HDPE
102
Extruding the polymer mixture
104
Generating artificial turf fibers from the extruded polymer mixture
106
Incorporating the artificial turf fibers into a carrier
108

Fig. 1

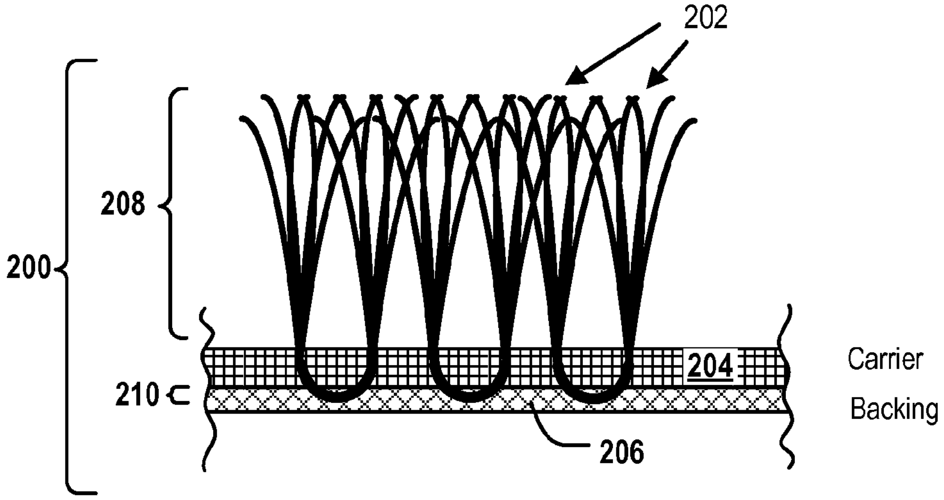
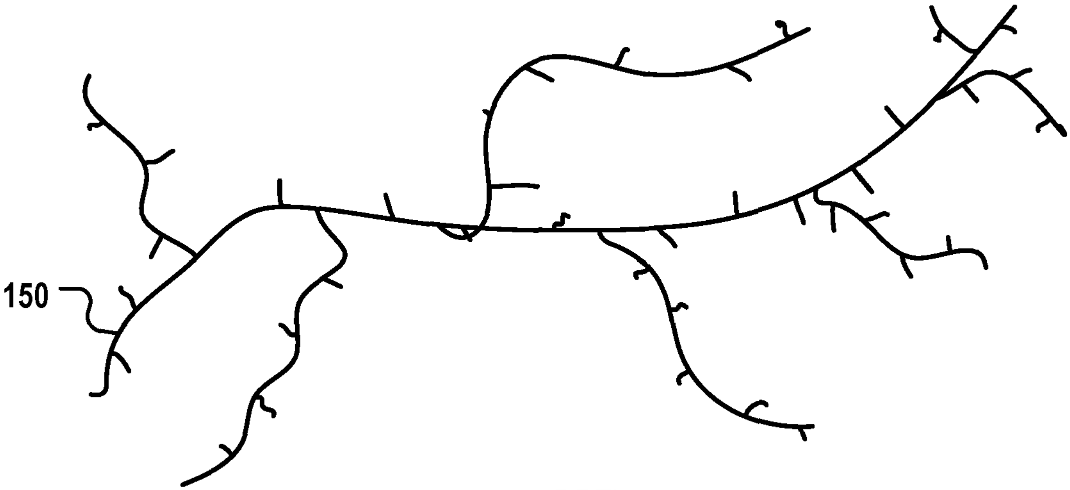

202
200
208
204
Carrier
210
Backing
206

Fig. 2



Low Density PE (LDPE)

Linear Low Density PE (LLDPE)

High Density PE (HDPE)

Fig. 3

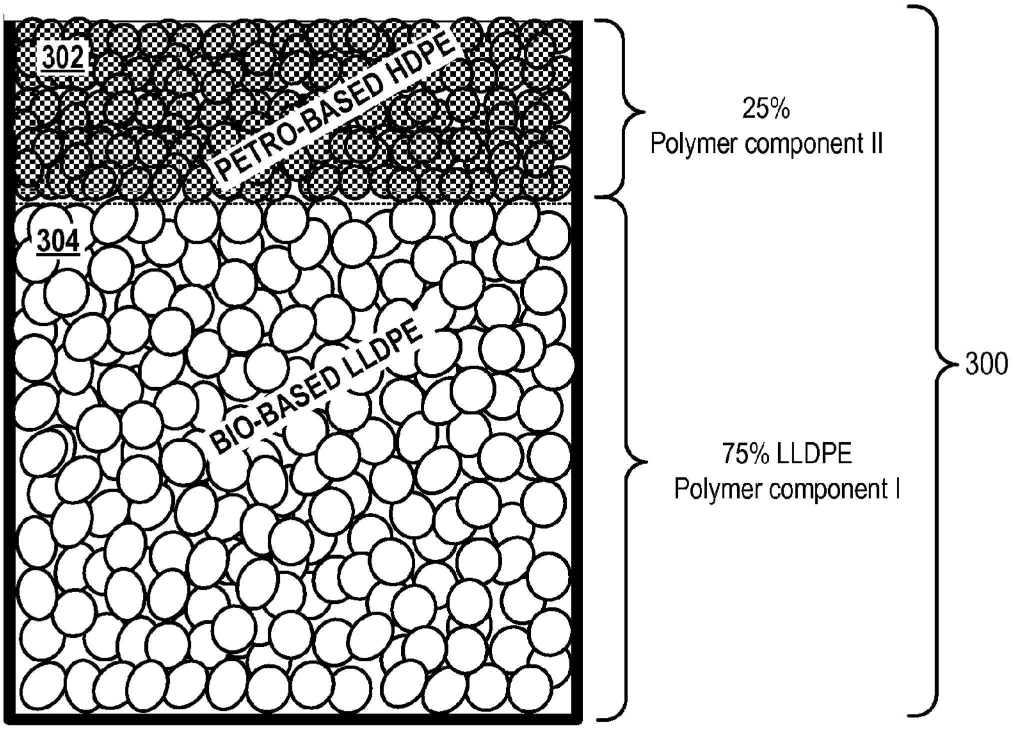

302
PETRO-BASED HDPE
25%
Polymer component II
304
BIO-BASED LLDPE
75% LLDPE
Polymer component I
300

Fig. 4

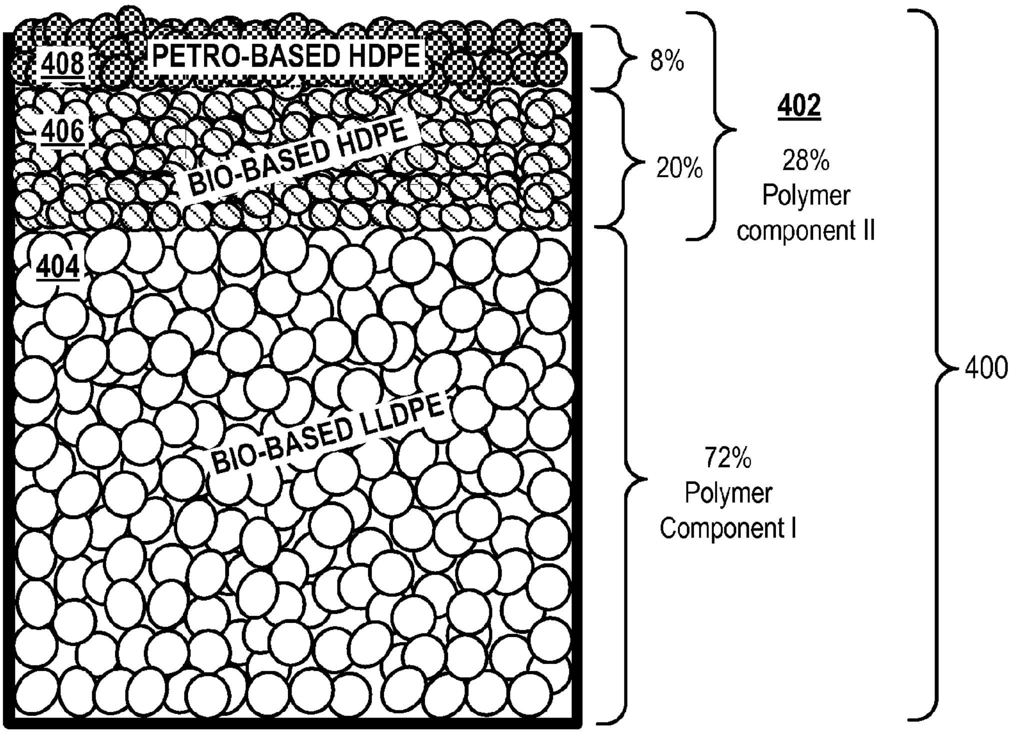

408
PETRO-BASED HDPE
8%
406
BIO-BASED HDPE
20%
402
28%
Polymer
component II
404
BIO-BASED LLDPE
72%
Polymer
Component I
400

Fig. 5

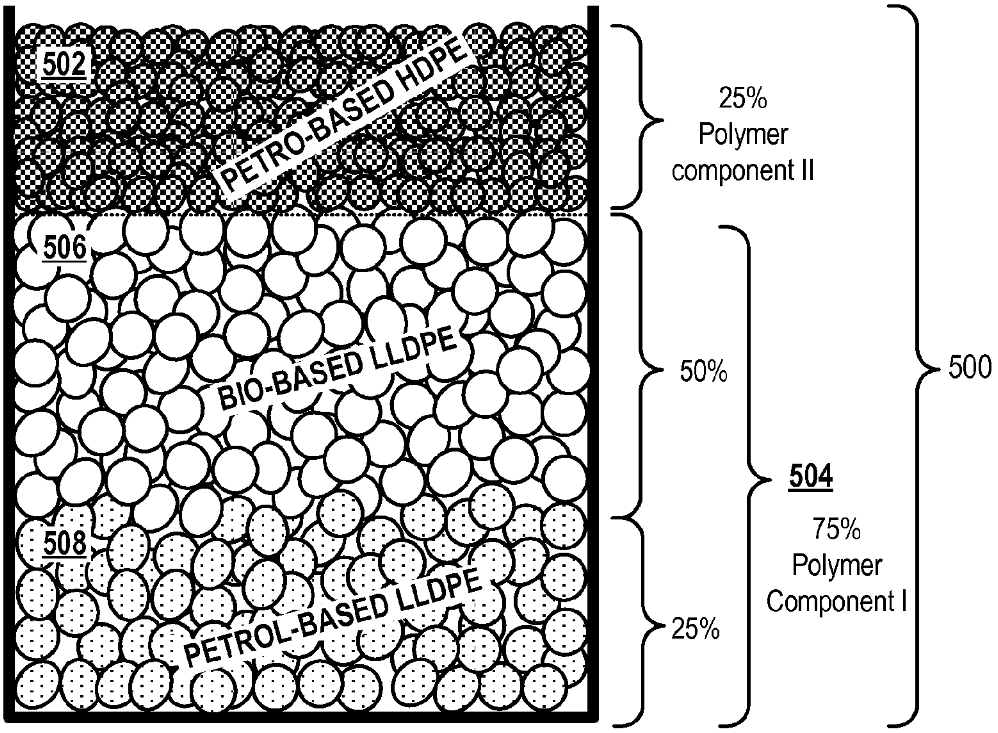

502
PETRO-BASED HDPE
25%
Polymer
component II
506
BIO-BASED LLDPE
50%
500
504
75%
Polymer
Component I
508
PETROL-BASED LLDPE
25%

Fig. 6

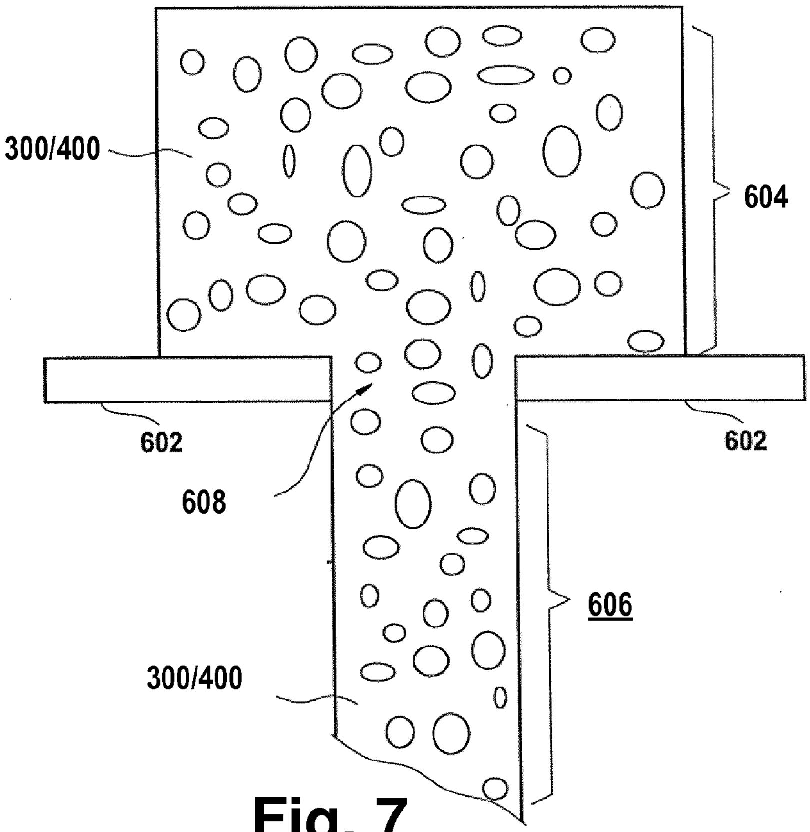

300/400
604
602
602
608
606
300/400

Fig. 7

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 16 19 6633

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,D	WO 2012/005974 A1 (DOW GLOBAL TECHNOLOGIES LLC [US]; SANDKUEHLER PETER [ES]; MARTIN JILL) 12 January 2012 (2012-01-12) * paragraphs [0042] - [0062], [0072]; claims 1,5,10-12,16 * -----	1-28	INV. D01F6/46 E01C13/08
X	JP H11 269811 A (DIATEX KK) 5 October 1999 (1999-10-05) * abstract; figures 1,2 * -----	1-28	
X	EP 2 039 831 A1 (DOMO ZELE NV [BE]) 25 March 2009 (2009-03-25) * paragraphs [0020], [0021], [0066]; claims 1,14,15 * -----	1-28	
X	EP 1 837 423 A1 (DOMO ZELE NV [BE]) 26 September 2007 (2007-09-26) * abstract; claims 1,2 * -----	1-28	
A	US 2011/120902 A1 (BOSWELL EMILY CHARLOTTE [US] ET AL) 26 May 2011 (2011-05-26) * claims 1-3 * -----	1-28	TECHNICAL FIELDS SEARCHED (IPC) D01F E01C

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	24 February 2017	Malik, Jan

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons
& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

EP 16 19 6633

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

24-02-2017

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
WO 2012005974 A1	12-01-2012	BR 112013000370 A2	07-06-2016
		CN 103080208 A	01-05-2013
		EP 2591050 A1	15-05-2013
		ES 2532105 T3	24-03-2015
		JP 2013542268 A	21-11-2013
		US 2013216736 A1	22-08-2013
		WO 2012004422 A1	12-01-2012
		WO 2012005974 A1	12-01-2012
JP H11269811 A	05-10-1999	JP 3342661 B2	11-11-2002
		JP H11269811 A	05-10-1999
EP 2039831 A1	25-03-2009	NONE	
EP 1837423 A1	26-09-2007	EP 1837423 A1	26-09-2007
		EP 2004885 A2	24-12-2008
		WO 2007107307 A2	27-09-2007
US 2011120902 A1	26-05-2011	CA 2825606 A1	02-08-2012
		CN 103328334 A	25-09-2013
		EP 2668105 A1	04-12-2013
		ES 2543152 T3	17-08-2015
		HK 1187585 A1	06-05-2016
		JP 5792834 B2	14-10-2015
		JP 2014508688 A	10-04-2014
		US 2011120902 A1	26-05-2011
		WO 2012102778 A1	02-08-2012

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

REFERENCES CITED IN THE DESCRIPTION

This list of references cited by the applicant is for the reader's convenience only. It does not form part of the European patent document. Even though great care has been taken in compiling the references, errors or omissions cannot be excluded and the EPO disclaims all liability in this regard.

Patent documents cited in the description

- EP 1378592 A, Slootweg **[0008]**
- WO 2006066777 A, Lambert **[0009]**
- WO 2008113566 A, Van Paridon **[0010]**
- WO 2008098905 A, Buriani **[0011]**
- WO 2011134897 A, Perdomi **[0012]**
- WO 2012005974 A, Sandkuehler **[0013]**

Non-patent literature cited in the description

- **DENISE FAN ; DER-JONG DAI ; HO-SHING WU.** Ethylene formation by catalytic dehydration of ethanol: industrial considerations. *Materials,* 2013, vol. 6, 101-115 **[0030]**
- **G. CHEN ; S. LI ; F. JIAO ; Q. YUAN.** Catalytic dehydration of bioethanol to ethylene over TiO_2/γ-Al_2O_3 catalysts in microchannel reactors. *Catalysis Today,* 2007, vol. 125, 111-119 **[0030]**