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(54) Title: POLYOLEFIN COMPOSITIONS AND PROCESS TO PRODUCE SUCH COMPOSITIONS BY THE ADDITION OF COUPLING AGENTS

(57) Abstract: The disclosure relates to a process to produce a polyolefin composition comprising a blend of polyethylene and polypropylene and to said polyolefin compositions. The process comprises the steps of: - providing from 10 to 90 wt.% of a component A, being one or more polyethylenes; - providing from 10 to 90 wt.% of a component B, being one or more polypropylenes; - providing a component H, wherein component H is one or more grafted and/or modified polyolefins selected from acid-grafted polyolefins and/or anhydride-modified polyolefins; wherein the polyolefin is selected from polyethylene and/or polypropylene; - melt-blending the components to form an intermediate polyolefin composition; - providing a component C, wherein component C is one or more coupling agents selected from one or more diol functionalized polymers and/or one or more metallic salts; - melt-blending the intermediate polyolefin composition with component C to form a polyolefin composition.



POLYOLEFIN COMPOSITIONS AND PROCESS TO PRODUCE SUCH COMPOSITIONS
BY THE ADDITION OF COUPLING AGENTS

TECHNICAL FIELD

5 The disclosure relates to a process for producing polyolefin compositions from polyethylene and polypropylene blends, wherein the polyolefin compositions have improved mechanical properties and to the polyolefin compositions obtained by such process. The disclosure also relates to a process for recycling waste thermoplastic polyolefin materials, comprising a blend of polyethylene and polypropylene, to obtain polyolefin compositions with good mechanical
10 properties and to the polyolefin composition obtained by said process.

TECHNICAL BACKGROUND

Blends of polyethylene (PE) and polypropylene (PP) have always been the subject of intense research for encouraging polymer waste recycling while producing new materials for specific applications in a sustainable way. However, being thermodynamically immiscible, these
15 polyolefins form a binary system that usually exhibits lower performances compared with those of the homopolymers. Many studies were carried out to better understand the PE/PP blend compatibilization for developing high-performance and cost-effective products. Both reactive and non-reactive compatibilization promote brittle to ductile transition for PE/PP blends. However, the final products do not usually meet the requirements for the current high
20 demanding commercial applications. Therefore, further PE/PP blend modifications with reinforcing filler either synthetic or natural, proved to be a good method for manufacturing high-performance reinforced polymer blend composites with superior and tailored properties.

WO2017/199202 relates to a process for recycling waste thermoplastic polymeric material by reacting, at the molten state, said waste thermoplastic polymeric material with an organic
25 compound containing one or more carbon-carbon double bonds. The reaction takes place in the presence of a free radical initiator. An increase of the molecular weight of the recycled polymers can be obtained and may be controlled by predetermined amounts and relative ratios between mono- or polyunsaturated functional compounds and free-radical initiators.

The use of recycled resin as a raw material for acid modified resins to accomplish an upgrade-
30 recycling of plastic wastes has been studied by Yuta Sunaga et al. in "Profitable Mass-Production of Acid-Modified Recovered Resins for Value-Added Mechanical Recycling as a Compatibilizer for Composites" ACS Sustainable Chem. Eng., 2018, 6 (9), pp 12110–12118. In this study, the polypropylene-rich recovered resin was subjected to acid modification with

maleic anhydride (MAH) and an organic peroxide. The obtained acid-modified recovered resins were used as compatibilizers for mass- production of wood/plastic composite (WPC).

CN 105 860 284 discloses compositions for extrusion for automobile parts. The technical filed is rubber material and in particular thermoplastic vulcanized rubber material. The compositions disclosed comprises rubber and silane coupling agent.

Thus, it is an object of the disclosure to provide polyolefin compositions comprising polyethylene and polypropylene having enhanced mechanical properties, such as an improved elongation at break and/or an improved impact resistance, articles made from such compositions and a process to produce such compositions.

It is also an object of the disclosure to provide polyolefin compositions comprising at least 50 wt.% of recycled polyolefins comprising polyethylene and polypropylene, wherein the compositions have enhanced mechanical properties, such as improved impact resistance and/or improved elongation at break; articles made from such compositions and a process to produce such compositions.

Summary

According to a first aspect, the disclosure provides a process to produce a polyolefin composition comprising a blend of polyethylene and polypropylene remarkable in that it comprises the steps of:

- providing from 10 to 90 wt.% based on the total weight of the polyolefin composition of a component A, wherein component A is one or more polyethylenes;
- providing from 10 to 90 wt.% based on the total weight of the polyolefin composition of a component B, wherein component B is one or more polypropylenes;
- providing a component H, wherein component H is one or more grafted and/or modified polyolefins selected from acid-grafted polyolefins and/or anhydride-modified polyolefins; wherein the polyolefin is selected from polyethylene and/or polypropylene;
- melt-blending the said components to form an intermediate polyolefin composition comprising acid-grafted polyolefin and/or anhydride-modified polyolefin;
- providing a component C, wherein component C is one or more coupling agents selected from one or more diol functionalized polymers and/or one or more metallic salts;
- melt-blending the intermediate polyolefin composition with component C to form a polyolefin composition.

In a preferred embodiment, component H is or comprises anhydride-modified polyolefin; wherein the polyolefin is selected from polyethylene and/or polypropylene, and the process further comprises:

- a step of providing water; and
- a step of melt-blending the components to form an intermediate polyolefin composition comprising anhydride-modified polyolefin wherein at least a part of the anhydride functions are hydrolyzed;

5 wherein the steps of providing water and of forming the intermediate polyolefin composition are conducted before the step of providing the components.

Thus, according to another definition, the disclosure in the first aspect provides a process to produce a polyolefin composition comprising a blend of polyethylene and polypropylene remarkable in that it comprises the steps of:

- 10 - providing from 10 to 90 wt.% based on the total weight of the polyolefin composition of a component A, wherein component A is one or more polyethylenes;
- providing from 10 to 90 wt.% based on the total weight of the polyolefin composition of a component B, wherein component B is one or more polypropylenes;
- providing a component H, wherein component H is one or more anhydride-modified
- 15 polyolefins, and optional one or more acid-grafted polyolefins; wherein the polyolefin is selected from polyethylene and/or polypropylene;
- providing water
- melt-blending the said components to form an intermediate polyolefin composition comprising anhydride-modified polyolefin and optional acid-grafted polyolefin, wherein at
- 20 least a part of the anhydride functions are hydrolysed;
- providing a component C, wherein component C is one or more coupling agents selected from one or more diol functionalized polymers and/or one or more metallic salts;
- melt-blending the intermediate polyolefin composition with component C to form a polyolefin composition.

25 Surprisingly it has been found that it was possible to produce polyolefin compositions comprising a blend of polyethylene and polypropylene, wherein the polyolefin compositions show improved mechanical properties, by grafting the polyethylene and/or the polypropylene with an anhydride or an acid, conducting a hydrolysis of the anhydride function, when present, to form an intermediate composition and blending with a coupling agent that will react with the

30 acid functions and/or hydrolysed anhydride functions, preferably hydrolysed maleic anhydride functions. Without being bound by theory, the coupling agent acts as a crosslinking agent reacting with the hydrolysed anhydride functions and/or the acid functions.

It is noted that US6569947 describes a maleic anhydride-modified ethylene polymer/ ionomer/ high-density polyethylene blend having improved impact resistance (e.g., increased low-

35 temperature Izod impact). This was achieved by the addition of a maleic anhydride grafted

high-density polyethylene derived polymer (e.g., MAN-g-HDPE, MAN-g-VLDPE, MAN-g-EPR, MAN-g-EPDM, and the like) to ionomer and to high-density polyethylene during blending. However, this document is silent regarding the possibility to improve the impact resistance in polyolefins blends comprising a mixture of polyethylene and polypropylene either from virgin
5 or recycled resins. This document is also silent regarding the possibility to improve the elongation at break for PE/PP blends, and to the possibility to use recycled resins.

In the following description, unless an explicit reference is made to the intermediate polyolefin composition, the wording “polyolefin composition” refers to the final composition obtained in the last step of the process.

10 According to the present disclosure, component C is selected from:

- one or more diol functionalized polymers; and/or
- one or more metallic salts.

When component C is or comprises one or more diol functionalized polymers, it is preferably selected from polybutadiene diol, poly farnesene diol, and polylactic acid diol; more preferably
15 component C is or comprises polybutadiene diol.

When component C is or comprises one or more metallic salts; it is preferably selected from zinc stearate, zinc acetate, sodium hydroxide and/or potassium hydroxide. With preference, component C is or comprises potassium hydroxide.

For example, component C comprises potassium hydroxide in a content of at least 0.5 wt.% based on the total weight of the polyolefin composition; with preference at least 0.8 wt.%.
20

For example, component C comprises potassium hydroxide in a content of at least 50 wt.% based on the total weight of component C; preferably at least 75 wt.%, more preferably 100 wt.%.

25 For example, component C comprises potassium hydroxide and the content of component B is at least 50 wt.% based on the total weight of the polyolefin composition; with preference, at least 60 wt.%.

The process comprises a step of addition of water and the content of the water melt-blended within the polyolefin composition preferably ranges from 0.1 to 10.0 wt.% based on the total
30 weight of the polyolefin composition without water; preferably 0.5 to 5.0 wt.%, more preferably from 1.0 to 3.0 wt.%.

In an embodiment, the content of component C ranges from 0.5 to 15 wt.% based on the total weight of the polyolefin composition, preferably from 0.6 to 10.0 wt.%, more preferably from 0.7 wt.% to 8.0 wt.%, even more preferably from 0.8 wt.% to 7.0 wt.%, most preferably from 0.9 wt.% to 6.0 wt.%, even most preferably from 1.0 wt.% to 5.0 wt.

- 5 For example, component C comprises one or more metallic salts and the content of the one or more metallic salts ranges from 0.5 to 10 wt.% based on the total weight of the polyolefin composition, preferably from 0.6 to 8.0 wt.%, more preferably from 0.7 wt.% to 5.0 wt.%, even more preferably from 0.8 wt.% to 4.0 wt.%, most preferably from 0.9 wt.% to 3.0 wt.%, even most preferably from 1.0 wt.% to 2.0 wt.

- 10 In an embodiment, the content of component H ranges from 0.5 to 15 wt.% based on the total weight of the polyolefin composition, preferably from 0.6 to 10.0 wt.%, more preferably from 0.7 wt.% to 8.0 wt.%, even more preferably from 0.8 wt.% to 7.0 wt.%, most preferably from 0.9 wt.% to 6.0 wt.%, even most preferably from 1.0 wt.% to 5.0 wt.

- In an embodiment, the total content of both component C and component H ranges from 1 to 30 wt.% based on the total weight of the polyolefin composition; preferably from 2 to 25 wt.%, more preferably from 3 to 20 wt.%, even more preferably from 4 wt.% to 15 wt.%, most preferably from 5 wt.% to 10 wt.%.

- In an embodiment, component H has a weight average molecular weight (M_w) of at least 10,000 g/mol, preferably at least 12,000 g/mol, more preferably at least 15,000 g/mol, even more preferably at least 20,000 g/mol, most preferably at least 30,000 g/mol, or at least 40,000 g/mol, or at least 45,000 g/mol, or at least 50,000 g/mol, or at least 55,000 g/mol, or at least 60,000 g/mol.

- In an embodiment, component H has a number average molecular weight (M_n) of at least 2,400 g/mol, more preferably at least 2,500 g/mol, even more preferably at least 3,000 g/mol, most preferably at least 5,000 g/mol, even most preferably at least 8,000 g/mol, or at least 10,000 g/mol, or at least 12,000 g/mol, or at least 13,000 g/mol, or at least 15,000 g/mol.

- For example, component H has a weight average molecular weight (M_w) of at least 10,000 g/mol and/or a number average molecular weight (M_n) of at least 2,400 g/mol. In an embodiment, component H is one or more grafted and/or modified polyolefins selected from acid-grafted polypropylene, acid-grafted polyethylene, anhydride-modified polypropylene, and anhydride-modified polyethylene.

With preference, component H is one or more grafted and/or modified polyolefins selected from acrylic acid-grafted polyolefin, fumaric acid-grafted polyolefin, maleic acid-grafted polyolefin, methacrylic acid-grafted polyolefin, nadic acid-grafted polyolefin, citraconic acid-

grafted polyolefin, itaconic acid-grafted polyolefin, acrylic anhydride-modified polyolefin, fumaric anhydride-modified polyolefin, maleic anhydride-modified polyolefin, methacrylic anhydride-modified polyolefin, nadic anhydride-modified polyolefin, citraconic anhydride-modified polyolefin, itaconic anhydride-modified polyolefin; wherein the polyolefin is selected from polyethylene and/or polypropylene.

In a preferred embodiment, component H is one or more maleic anhydride-modified polyolefins selected from one or more maleic anhydride-modified polyethylenes and/or one or more maleic anhydride-modified polypropylenes.

In a preferred embodiment, the component A and/or the component B are recycled resins selected from post-consumer resins (PCR) and/or post-industrial resins (PIR); with preference:

- the total content of the recycled resins (RR_T) in the polyolefin composition ranges from 50 to 99 wt.% based on the total weight of the polyolefin composition; and/or
- the components A and B are provided separately as a polyethylene recycled resin (rPE), and a polypropylene recycled resin (rPP); or the component A and B are provided together as a polyolefin recycled resin (rPO).

In particular, when both components A and B are recycled resins, the process preferably further comprises, before the step of melt blending the components to form an intermediate polyolefin composition, one or more steps selected from:

- providing a component D being at least one virgin polyethylene, with preference component D has an MI₂ ranging from 0.10 to 70.0 g/10 min as determined according to ISO 1133:1997 conditions D, at a temperature of 190°C and under a load of 2.16 kg; and/or
- providing a component E being at least one virgin polypropylene, with preference component E has an MI₂ ranging from 1.0 to 200.0 g/10 min as determined according to ISO 1133:1997 conditions M, at a temperature of 230°C and under a load of 2.16 kg.

With preference, one or more of the following embodiments can be used to better define the component A to be used in the process:

- Component A is a virgin resin, or component A is a recycled polyethylene resin (rPE) selected from post-consumer resin (PCR_A) and/or post-industrial resins (PIR_A).

- Component A is a recycled resin selected from one or more polyethylene post-consumer resins (PCR-PE), polyethylene post-industrial resins (PIR-PE), polyolefin post-consumer resin (PCR-PO), and polyolefin post-industrial resins (PIR-PO).
- The content of component A ranges from 15 to 85 wt.% based on the total weight of the polyolefin composition, preferably, from 20 to 80 wt.%, more preferably from 25 wt.% to 75 wt.% and even more preferably from 30 to 70 wt.%.
- Component A has an MI₂ ranging from 0.10 to 70.0 g/10 min as determined according to ISO 1133:1997 conditions D, at a temperature of 190°C and under a load of 2.16 kg; preferably from 0.25 to 25.0 g/10 min.
- Component A has a density ranging from 0.820 to 0.980 g/cm³ as determined according to ISO 1183 at a temperature of 23°C.

With preference, one or more of the following embodiments can be used to better define the component B to be used in the process:

- Component B is a virgin resin or component B is a recycled polypropylene resin (rPP) selected from post-consumer resin (PCR_B) and/or post-industrial resins (PIR_B).
- Component B is a recycled resin selected from one or more polypropylene post-consumer resins (PCR-PP), polypropylene post-industrial resins (PIR-PP), polyolefin post-consumer resin (PCR-PO), and polyolefin post-industrial resins (PIR-PO).
- The content of component B ranges from 15 to 85 wt.% based on the total weight of the polyolefin composition, preferably, from 20 to 80 wt.%, more preferably from 25 wt.% to 75 wt.% and even more preferably from 30 to 70 wt.%.
- Component B has an MI₂ ranging from 1.0 to 200.0 g/10 min as determined according to ISO 1133:1997 conditions M, at a temperature of 230°C and under a load of 2.16 kg; preferably from 5.0 to 50.0 g/10 min.
- Component B has a density ranging from 0.870 to 0.946 g/cm³ as determined according to ISO 1183 at a temperature of 23°C, preferably ranging from 0.890 to 0.940 g/cm³; more preferably ranging from 0.900 to 0.930 g/cm³.

For example, the component A and the component B are in a weight ratio ranging between 5:1 to 1:5, preferably between 3:1 to 1:3, more preferably between 2:1 to 1:2 and most preferably being 1:1.

With preference, the component A and B are provided together as recycled polyolefin resin (rPO) selected from polyolefin post-consumer resin (PCR-PO) and/or polyolefin post-industrial resins (PIR-PO); and one or more of the following embodiments can be used to better define the recycled polyolefin resin (rPO) to be used in the process:

- The recycled polyolefin resin (rPO) comprises at least 30 wt.% of polyethylene based on the total weight of the recycled polyolefin resin and/or comprises at least 30 wt.% of polypropylene based on the total weight of the recycled polyolefin resin.

In a preferred embodiment, before the step of melt blending the components to form a polyolefin composition, the process further comprises a step of providing a component F being one or more fillers, and the step of melt-blending the components to form a polyolefin composition comprises melt-blending component F with the other components to form the polyolefin composition. With preference, one or more of the following embodiments can be used to better define the component F to be used in the process:

- 10 - The content of component F ranges from 0 to 50 wt.% based on the total weight of the polyolefin composition; preferably from 0.1 to 50.0 wt.%, more preferably from 0.2 wt.% to 40.0 wt.%, even more preferably from 0.5 wt.% to 30.0 wt.%, most preferably from 1.0 wt.% to 20 wt.%, even most preferably from 1.5 wt.% to 15.0 wt.%, or from 2.5 wt.% to 12.5 wt.%, or from 5.0 wt.% to 10.0 wt.%
- 15 - Component F comprises one or more reinforcement materials selected from talc mineral filler, wollastonite, calcium carbonate, modified calcium carbonate, coated calcium carbonate, glass fibres, bamboo fibres, flax fibres, hemp fibres, carbon black, carbon nanotubes, graphene nanotubes, and any mixture thereof; with preference, component F comprises one or more reinforcement materials selected from talc, glass
- 20 fibres and carbon nanotubes; more preferably, component F comprises one or more reinforcement materials selected from glass fibres and carbon nanotubes.

In a preferred embodiment, before the step of melt blending the components to form a polyolefin composition, the process further comprises a step of providing a component G being one or more elastomers, and the step of melt-blending the components to form a polyolefin composition comprises melt-blending the component G with the other components to form the polyolefin composition. With preference, one or more of the following embodiments can be used to better define the component G to be used in the process:

- 25 - The content of component G ranges from 0 to 10 wt.% based on the total weight of the polyolefin composition; preferably from 0.1 to 10.0 wt.%, more preferably from 0.2 wt.% to 9.8 wt.%, even more preferably from 0.5 wt.% to 9.5 wt.%, most preferably from 1.0 wt.% to 9.3 wt.%, even most preferably from 1.5 wt.% to 9.1 wt.%, or from 2.5 wt.% to 9.0 wt.%, or from 5.0 wt.% to 8.5 wt.%.
30 - The component G, being one or more elastomers, has an MI₂ ranging from 0.5 to 5.0 g/10 min as determined according to ISO 1133:1997 conditions D, at a temperature of 190 °C and under a load of 2.16 kg, preferably the component G has an MI₂ of at
35 most 4.5 g/10 min, more preferably of at most 4.0 g/10 min, even more preferably of at

most 3.5 g/10 min, most preferably of at most 3.0 g/10 min, even most preferably of at most 2.5 g/10 min or of at most 2.0 g/10 min.

- Component G is selected from elastomeric copolymers of ethylene with 1-octene, elastomeric copolymers of ethylene with 1-butene; elastomeric copolymers of ethylene with propene, and any mixture thereof; and/or from SIS (Styrene isoprene styrene block copolymers), SEPS (Hydrogenated styrene isoprene styrene block copolymers), SBS (Styrene butadiene styrene block copolymers), SEBS (Hydrogenated styrenic butadiene copolymers), SBSS (Styrene butadiene styrene styrene block copolymers), and any mixture thereof.

- 10 The steps of providing components F and G, when both conducted, can be performed in any order or simultaneously.

In preferred embodiments, the process is devoid of a step of addition of peroxides.

According to a second aspect, the disclosure provides a polyolefin composition produced by a process according to the first aspect, wherein the polyolefin composition comprises

- 15 - from 10 to 90 wt.% based on the total weight of the polyolefin composition of a component A being of one or more polyethylenes;
- from 10 to 90 wt.% based on the total weight of the polyolefin composition of a component B being one or more polypropylenes;
- a component C, wherein component C is one or more coupling agents selected from one or more diol functionalized polymers and/or one or more metallic salts; and
- 20 - a component H being one or more grafted and/or modified polyolefins selected from acid-grafted polyolefins and/or anhydride-modified polyolefins; wherein the polyolefin is selected from polyethylene and/or polypropylene.

Preferably the polyolefin composition is produced by a process according to the first aspect.

- 25 For example, the coupling agent is potassium hydroxide.

For example, component C comprises at least 50 wt.% based on the total weight of component C of potassium hydroxide; preferably at least 75 wt.%, more preferably 100 wt.%

With preference, the total content of the component C and the component H ranges from 1 to 30 wt.% based on the total weight of the polyolefin composition.

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For example, the component A and the component B are in a weight ratio ranging between 5:1 to 1:5, preferably between 3:1 to 1:3, more preferably between 2:1 to 1:2 and most preferably being 1:1.

In a preferred embodiment, the polypropylene (i.e. component B) and the polyethylene (i.e. component A) are in a weight ratio of 1:1 and in co-continuous phases.

In another embodiment, the content of the polyethylene (i.e. component A) is at least 60 wt. % based on the total weight of the polyolefin composition and the polypropylene (i.e. component B) has a droplet dispersion within the polyethylene (i.e. component A).

In another embodiment, the content of the polypropylene (i.e. component B) is at least 60 wt. % based on the total weight of the polyolefin composition and the polyethylene (i.e. component A) has a droplet dispersion within the polypropylene (i.e. component B).

According to a third aspect, the disclosure provides the use of the polyolefin composition obtained by the process according to the first aspect, or of the polyolefin composition of the second aspect, to make an article in a process selected from 3D-printing, extrusion, blow-moulding, injection, injection blow moulding, injection stretch blow moulding, rotomoulding, extrusion and thermoforming.

According to a fourth aspect, the disclosure provides an article made from the polyolefin composition obtained by the process according to the first aspect, or by the polyolefin composition of the second aspect, preferably:

- the article is a thermoformed article or a moulded article selected from injection moulded article, compression moulded article, rotomoulded article, injection blow moulded article, and injection stretch blow moulded article, and/or
- the article is selected from the group consisting of automobile parts, non-food packaging, retort packaging, housewares, caps, closures, media packaging and medical devices.

According to a fifth aspect, the disclosure provides the use of a component C being one or more coupling agents in a polyolefin composition comprising a component A being one or more polyethylene, a component B being one or more polypropylenes and a component H being one or more grafted and/or modified polyolefins selected from acid-grafted polyolefin and/or anhydride-modified polyolefin; wherein the polyolefin is selected from polyethylene and/or polypropylene; wherein component C is selected from one or more diol functionalized polymers; and/or one or more metallic salts; wherein the use comprises:

- the hydrolysis of the anhydride functions when present to form an intermediate polyolefin composition, before the addition of the coupling agent to form the polyolefin composition; and/or
- the coupling agent comprising potassium hydroxide and the content of component B is at least 50 wt. % based on the total weight of the polyolefin composition; preferably the

coupling agent is potassium hydroxide and/or the content of component B being at least 60 wt.% based on the total weight of the polyolefin composition.

DETAILED DESCRIPTION

5 For the purpose of the disclosure, the following definitions are given.

The terms "comprising", "comprises" and "comprised of" as used herein are synonymous with "including", "includes" or "containing", "contains", and are inclusive or open-ended and do not exclude additional, non-recited members, elements or method steps. The terms "comprising", "comprises" and "comprised of" also include the term "consisting of".

10 The recitation of numerical ranges by endpoints includes all integer numbers and, where appropriate, fractions subsumed within that range (e.g. 1 to 5 includes 1, 2, 3, 4 when referring to, for example, a number of elements, and can also include 1.5, 2, 2.75 and 3.80, when referring to, for example, measurements). The recitation of endpoints also includes the recited endpoint values themselves (e.g. from 1.0 to 5.0 includes both 1.0 and 5.0). Any numerical
15 range recited herein is intended to include all sub-ranges subsumed therein.

The reference throughout this specification to "one embodiment" or "an embodiment" means that a particular feature, structure or characteristic described in connection with the embodiment is included in at least one embodiment of the present disclosure. The particular features, structures, characteristics or embodiments may be combined in any suitable manner,
20 as would be apparent to a person skilled in the art from this disclosure, in one or more embodiments. Furthermore, while some embodiments described herein include some but not other features included in other embodiments, combinations of features of different embodiments are meant to be within the scope of the disclosure and form different embodiments, as would be understood by those in the art.

25 Unless otherwise defined, all terms used in disclosing the disclosure, including technical and scientific terms, have the meaning as commonly understood by one skilled in the art to which this disclosure belongs. By means of further guidance, definitions for the terms used in the description are included to better appreciate the teaching of the present disclosure.

As used herein, the terms "melt blending" involve the use of shear force, extensional force,
30 compressive force, ultrasonic energy, electromagnetic energy, thermal energy or combinations comprising at least one of the foregoing forces or forms of energy and is conducted in a processing equipment wherein the aforementioned forces are exerted by a single screw, multiple screws, intermeshing co-rotating or counter-rotating screws, non-intermeshing co-rotating or counter-rotating screws, reciprocating screws, screws with pins,

barrels with pins, rolls, rams, helical rotors, or combinations comprising at least one of the foregoing. Melt blending may be conducted in machines such as, single or multiple screw extruders, Buss kneader, Eirich mixers, Henschel, helicones, Ross mixer, Banbury, roll mills, moulding machines such as injection moulding machines, vacuum forming machines, blow
5 moulding machines, or the like, or combinations comprising at least one of the foregoing machines. It is generally desirable during melting or solution blending of the composition to impart specific energy of about 0.01 to about 10 kilowatt-hours/kilogram (kW h/kg) to the composition. In a preferred embodiment, melt blending is performed in a twin-screw extruder, such as a Brabender co-rotating twin-screw extruder.

10 The terms "polypropylene" (PP) and "propylene polymer" may be used synonymously. The term "polypropylene" encompasses homopolymers of propylene as well as copolymers of propylene which can be derived from propylene and one or more comonomers selected from the group consisting of ethylene and C₄-C₂₀ alpha-olefins, such as 1-butene, 1-pentene, 4-methyl-1-pentene, 1-hexene, 1-octene, 1-decene, 1-dodecene, 1-tetradecene, 1-hexadecene,
15 1-octadecene and 1-eicosene.

The terms "polyethylene" (PE) and "ethylene polymer" may be used synonymously. The term "polyethylene" encompasses homopolymers of ethylene as well as copolymers of ethylene which can be derived from ethylene and one or more comonomers selected from the group consisting of C₃-C₂₀ alpha-olefins, such as propylene, 1-butene, 1-pentene, 4-methyl-1-
20 pentene, 1-hexene, 1-octene, 1-decene, 1-dodecene, 1-tetradecene, 1-hexadecene, 1-octadecene and 1-eicosene.

The term "copolymer" refers to a polymer which is made by linking a monomer and at least one comonomer in the same polymer chain. The term "homopolymer" refers to a polymer which is made in the absence of comonomer or with less than 0.1 wt.%, more preferably less
25 than 0.05 wt.%, most preferably less than 0.005 wt.% of comonomer based on the total weight of the polymer.

The terms "polypropylene resin" or "polyethylene resin", as used herein, refer to polypropylene or polyethylene fluff or powder that is extruded, and/or melted and/or pelletized and can be produced through compounding and homogenizing of the polypropylene resin or the
30 polyethylene resin as taught herein, for instance, with mixing and/or extruder equipment. As used herein, the term "polypropylene" may be used as a shorthand for "polypropylene resin", idem for "polyethylene" that can be used as a shorthand for "polyethylene resin". The terms "fluff" or "powder" as used herein refer to polypropylene material with the hard catalyst particle at the core of each grain and is defined as the polymer material after it exits the polymerization
35 reactor (or the final polymerization reactor in the case of multiple reactors connected in series).

Under normal production conditions in a production plant, it is expected that the melt index (MI2) will be different for the fluff than for the polyethylene resin or for the polypropylene resin. Under normal production conditions in a production plant, it is expected that the density will be slightly different for the fluff, than for the polyethylene resin or for the polypropylene resin.

5 Unless otherwise indicated, density and melt index for the polyethylene resin or for the polypropylene resin refer to the density and melt index as measured on the polyethylene resin or on the polypropylene resin as defined above.

The terms "virgin polyethylene" are used to denote a polyethylene directly obtained from a polyethylene polymerization plant. The terms "directly obtained" is meant to include that the
10 polyethylene may optionally be passed through a pelletization step or an additivition step or both.

The terms "virgin polypropylene" are used to denote a polypropylene directly obtained from a propylene polymerization plant. The terms "directly obtained" is meant to include that the polypropylene may optionally be passed through a pelletization step or an additivition step or
15 both.

The terms "recycled resins" encompasses both Post-Consumer Resins (PCR) and Post-Industrial Resins (PIR).

The terms "Post-Consumer Resin", which may be abbreviated as "PCR", is used to denote the components of domestic waste, household waste or end of life vehicle waste. In other
20 words, the PCR are made of recycled products from waste created by consumers.

The terms "Post-Industrial Resin", which may be abbreviated as "PIR", is used to denote the waste components from pre-consumer resins during packaging processes. In other words, the PIR are made of recycled products created from scrap by manufacturers.

The terms "polyolefin recycled resin" (rPO), "polyolefin post-consumer resin" (PCR-PO) and
25 "polyolefin post-industrial resin" (PIR-PO) denote recycled materials that are compounds made of high-density polyethylene, low-density polyethylene, linear low-density polyethylene and polypropylene. The content of polypropylene in polyolefin recycled resin is higher than the content of polypropylene in polyethylene post-consumer resins and in post-industrial resins.

As used herein, "blend", "polymer blend" and like terms refer to a composition of two or more
30 compounds, for example, two or more polymers or one polymer with at least one other compound.

The particular features, structures, characteristics or embodiments may be combined in any suitable manner, as would be apparent to a person skilled in the art from this disclosure, in one or more embodiments.

The disclosure provides a process to produce a polyolefin composition comprising a blend of polyethylene and polypropylene characterized in that it comprises the steps of:

- providing from 10 to 90 wt.% based on the total weight of the polyolefin composition of a component A, wherein component A is one or more polyethylenes;
- providing from 10 to 90 wt.% based on the total weight of the polyolefin composition of a component B, wherein component B is one or more polypropylenes;
- providing a component H, wherein component H is one or more grafted and/or modified polyolefins selected from acid-grafted polyolefins and/or anhydride-modified polyolefins; wherein the polyolefin is selected from polyethylene and/or polypropylene; melt-blending the said components to form an intermediate polyolefin composition comprising acid-grafted polyolefin and/or anhydride-modified polyolefin;
- providing a component C, wherein component C is one or more coupling agents selected from one or more diol functionalized polymers and/or one or more metallic salts;
- melt-blending the intermediate polyolefin composition with component C to form a polyolefin composition.

For example, the component A and the component B are in a weight ratio ranging between 5:1 to 1:5, preferably between 3:1 to 1:3, more preferably between 2:1 to 1:2 and most preferably being 1:1.

In a preferred embodiment, component H is or comprises anhydride-modified polyolefin; wherein the polyolefin is selected from polyethylene and/or polypropylene, and the process further comprises:

- a step of providing water; and
- a step of melt-blending the components to form an intermediate polyolefin composition comprising anhydride-modified polyolefin wherein at least a part of the anhydride functions is hydrolyzed;

wherein the steps of providing water and of forming the intermediate polyolefin composition are conducted before the step of providing the components.

Thus, the process to produce a polyolefin composition comprising a blend of polyethylene and polypropylene can be defined as comprising the steps of:

- providing from 10 to 90 wt.% based on the total weight of the polyolefin composition of a component A, wherein component A is one or more polyethylenes;
- providing from 10 to 90 wt.% based on the total weight of the polyolefin composition of a component B, wherein component B is one or more polypropylenes;
- 5 - providing a component H, wherein component H is one or more anhydride-modified polyolefins, and optional one or more acid-grafted polyolefins; wherein the polyolefin is selected from polyethylene and/or polypropylene;
- providing water
- melt-blending the said components to form an intermediate polyolefin composition
- 10 comprising anhydride-modified polyolefin and optional acid-grafted polyolefin, wherein at least a part of the anhydride functions are hydrolysed;
- providing a component C, wherein component C is one or more coupling agents selected from one or more diol functionalized polymers and/or one or more metallic salts;
- melt-blending the intermediate polyolefin composition with component C to form a
- 15 polyolefin composition.

In a preferred embodiment, the content of the water melt-blended to form the intermediate polyolefin composition preferably ranges from 0.1 to 10.0 wt.% based on the total weight of the polyolefin composition without water; preferably 0.5 to 5.0 wt.%, more preferably from 1.0 to 3.0 wt.%.

20

According to the disclosure, the components A and B can be selected from virgin resins or from recycled resins. When component A and/or component B are recycled resins, they can be submitted to a fine grinding step before being melt-blended, in order to obtain a powder. Indeed, when component A and/or component B are recycled resins, they may be provided in

25 flakes or pellets form. Optionally, component A and/or component B are provided in a powder form. The recycled resins that are provided in flakes form have been used and collected as waste. If the recycled resins are further extruded and filtered, they are provided in pellets form.

In an embodiment, the step of melt blending is performed with a co-rotating twin-screw extruder. The step of melt blending is performed in an extruder at a screw speed of at least

30 100 rpm, preferably of at least 120 rpm. For example, the screw speed may range from 150 rpm to 1200 rpm. When component A and/or component B are recycled resins, the step of melt-blending to form a polyolefin composition comprises passing the melted polyolefin composition through one or more screen filters having a mesh size ranging from 40 to 220 microns, preferably from 80 to 200 microns and isolating the filtered polyolefin composition.

35

Selection of the polyethylene (components A and D)

With preference, component A and/or component D have an MI2 of at most 70.0 g/10 min as determined according to ISO 1133:1997 conditions D, at a temperature of 190°C and under a load of 2.16 kg, preferably of at most 50.0 g/10 min, more preferably at most 25.0 g/10 min, or at most 20 g/10 min, even more preferably at most 15 g/10 min, and most preferably of at most 10.0 g/10 min, even most preferably of at most 5.0 g/10 min, or of at most 3.0 g/10 min, or of at most 2.0 g/10 min, or of at most 1.5 g/10 min, or of at most 1.0 g/10 min.

Preferably, component A and/or component D have an MI2 of at least 0.10 g/10 min as determined according to ISO 1133:1997 conditions D, at a temperature of 190°C and under a load of 2.16 kg, preferably of at least 0.15 g/10 min, more preferably at least 0.20 g/10 min, and even more preferably at least 0.25 g/10 min or at least 0.30 g/10 min, or at least 0.40 g/10 min, or at least 0.50 g/10 min.

For example, component A and/or component D have an MI2 ranging from 0.10 to 70.0 min as determined according to ISO 1133:1997 conditions D, at a temperature of 190°C and under a load of 2.16 kg, preferably from 0.10 to 50.0 g/10 min, more preferably from 0.10 to 25.0 g/10 min, even more preferably from 0.10 to 15 g/10 min, most preferably from 0.10 to 10.0 g/10 min, even most preferably from 0.10 to 5.0 g/10 min, or from 0.10 to 3.0 g/10 min, or from 0.15 to 2.0 g/10 min, or from 0.20 to 1.5 g/10 min, or from 0.25 to 1.0 g/10 min, or from 0.5 to 1.0 g/10 min, or from 0.25 to 25.0 g/10 min.

When component A and/or component D contains two or more polyethylene resins of different melt index, the MI2 to be considered is the MI2 measured on the mixture of said two or more polyethylene resins.

In an embodiment, component A and/or component D has a monomodal molecular weight distribution. In another embodiment, component A and/or component D has a multimodal molecular weight distribution, preferably a bimodal molecular weight distribution. Component A and/or component D may be monomodal or multimodal.

As used herein, the terms “monomodal polyethylene” or “polyethylene with a monomodal molecular weight distribution” refers to polyethylene having one maximum in their molecular weight distribution curve, which is also defined as a unimodal distribution curve. As used herein, the terms “polyethylene with a bimodal molecular weight distribution” or “bimodal polyethylene” refer to polyethylene having a distribution curve being the sum of two unimodal molecular weight distribution curves, and refer to a polyethylene product having two distinct but possibly overlapping populations of polyethylene macromolecules each having different weight average molecular weights.

As used herein, the terms “polyethylene with a multimodal molecular weight distribution” or “multimodal polyethylene” refer to polyethylene with a distribution curve is the sum of at least two, preferably more than two unimodal distribution curves, and refer to a polyethylene product having two or more distinct but possibly overlapping populations of polyethylene macromolecules each having different weight average molecular weights. The multimodal polyethylene can have an “apparent monomodal” molecular weight distribution, which is a molecular weight distribution curve with a single peak and no shoulder. In an embodiment, said polyethylene resin having a multimodal, preferably bimodal, molecular weight distribution can be obtained by physically blending at least two polyethylene fractions.

10 The density of component A and/or component D ranges from 0.820 g/cm³ to 0.980 g/cm³. Preferably, the polyethylene has a density of at most 0.960 g/cm³. Preferably, the polyethylene has a density of at least 0.850 g/cm³, more preferably of at least 0.900 g/cm³, even more preferably of at least 0.910 g/cm³ and most preferably of at least 0.915 g/cm³. The density is determined according to ISO 1183 at a temperature of 23 °C.

15 Component A and/or component D comprises linear low-density polyethylene (LLDPE), low-density polyethylene (LDPE), medium-density polyethylene (MDPE), high-density polyethylene (HDPE), and mixtures thereof.

Component A and/or component D comprises one or more polyethylenes selected from ethylene homopolymers, copolymers of ethylene and at least one comonomer, or mixture thereof. Suitable comonomers comprise but are not limited to aliphatic C₃-C₂₀ alpha-olefins. Examples of suitable aliphatic C₃-C₂₀ alpha-olefins include propylene, 1-butene, 1-pentene, 4-methyl-1-pentene, 1-hexene, 1-octene, 1-decene, 1-dodecene, 1-tetradecene, 1-hexadecene, 1-octadecene and 1-eicosene.

25 The term “copolymer” refers to a polymer which is made by linking ethylene and at least one comonomer in the same polymer chain. The term “homopolymer” refers to a polymer which is made in the absence of comonomer or with less than 0.1 wt.%, more preferably less than 0.05 wt.%, most preferably less than 0.005 wt.% of comonomer based on the total weight of the polymer.

30 In case of component A, and/or component D, is or comprises an ethylene copolymer, it comprises at least 0.1 wt.% of comonomer, preferably at least 1 wt.% based on the total weight of the copolymer. The ethylene copolymer comprises up to 10 wt.% of comonomer based on the total weight of the copolymer, and most preferably up to 6 wt.%. In an embodiment of the disclosure, the comonomer is 1-hexene.

The content of component A in the polyolefin composition is at least 10 wt.% based on the total weight of the polyolefin composition, preferably at least 15 wt.% or at least 20 wt.%, more preferably at least 25 wt.% or at least 27 wt.% or at least 30 wt.%, even more preferably at least 40 wt.%, most preferably at least 50 wt.%, and even most preferably at least 60 wt.%, or at least 70 wt.%.

The content of component A in the polyolefin composition is at most 90 wt.% based on the total weight of the polyolefin composition, preferably at most 85 wt.% or at most 80 wt.%, more preferably at most 75 wt.% or at most 70 wt.%, even more preferably at most 67 wt.% or at most 65 wt.% or at most 60 wt.%, most preferably at most 50 wt.%, and even most preferably at most 40 wt.%, or at most 30 wt.%.

The content of component D in the polyolefin composition is at least 10 wt.% based on the total weight of the polyolefin composition, preferably at least 15 wt.% or at least 20 wt.%, more preferably at least 25 wt.% or at least 27 wt.% or at least 30 wt.%, even more preferably at least 40 wt.%, most preferably at least 50 wt.%, and even most preferably at least 60 wt.%, or at least 70 wt.%.

The content of component D in the polyolefin composition is at most 90 wt.% based on the total weight of the polyolefin composition, preferably at most 85 wt.% or at most 80 wt.%, more preferably at most 75 wt.% or at most 70 wt.%, even more preferably at most 67 wt.% or at most 65 wt.% or at most 60 wt.%, most preferably at most 50 wt.%, and even most preferably at most 40 wt.%, or at most 30 wt.%.

Non-exhaustive specific examples of commercially available virgin polyethylene resins that can be used as component A and/or component D in the process are:

- HDPE 5502 produced by TOTAL, having an MI2 of 0.25 g/10 min and a density of 0.954 g/cm³.
- Lumicene Supertough 22ST05 produced by TOTAL, having an MI2 of 0.5 g/10 min and a density of 0.932 g/cm³.
- FE 8000 produced by TOTAL, having an MI2 of 0.8 g/10 min and a density of 0.924 g/cm³.
- Lumicene M2710EP produced by TOTAL, having an MI2 of 0.9 g/10 min and a density of 0.927 g/cm³.
- Q1018N produced by TOTAL, having an MI2 of 1.0 g/10 min and a density of 0.918 g/cm³.

An example of a commercially available stream of polyethylene post-consumer resin (PCR-PE) that can be used as component A (PCR_A) suitable for the process of the disclosure is KWR105M2 marketed by KW Plastics.

5 The polyethylene post-consumer resin (PCR-PE) that can be used in accordance with the disclosure is preferably selected from HDPE dairy packaging waste.

In a preferred embodiment, the polyethylene recycled resin (rPE) that can be used in accordance with the disclosure comprises less than 10 wt.% based on the total weight of the recycled resin of polymers other than polyethylene. For example, the polyethylene recycled resin may contain up to 10 wt.% of polypropylene based on the total weight of the polyethylene recycled resin (rPE).
10

The use of a polyethylene recycled resin (rPE and/or rPO) as component A allows the increase of the total content of the recycled resins in the polyolefin composition.

The presence of component D in the polyolefin composition is optional. Component D comprises one or more polyethylenes and may be present when component A is a recycled resin selected from a polyethylene post-consumer resin (PCR-PE), a polyolefin post-consumer resin (PCR-PO), a polyethylene post-industrial resin (PIR-PE), a polyolefin post-industrial resin (PIR-PO), or a mixture thereof.
15

Selection of the polypropylene (components B and E)

20 With preference, component B and/or component E have an MI₂ of at most 200.0 g/10 min as determined according to ISO 1133:1997 conditions M, at a temperature of 230°C and under a load of 2.16 kg, preferably of at most 150.0 g/10 min, more preferably at most 100.0 g/10 min or at most 80.0 g/10 min, even more preferably at most 50.0 g/10 min, most preferably of at most 30.0 g/10 min or at most 25.0 g/10 min, even most preferably of at most 20.0 g/10 min,
25 or of at most 15.0 g/10 min.

Preferably, component B and/or component E have an MI₂ of at least 1.0 g/10 min as determined according to ISO 1133:1997 conditions M, at a temperature of 230°C and under a load of 2.16 kg, preferably of at least 2.0 g/10 min or at least 3.0 g/10 min, more preferably at least 5.0 g/10 min, even more preferably at least 6.0 g/10 min, most preferably of at least 7.0
30 and even most preferably of at least 10.0 g/10 min.

For example, component B and/or component E has an MI₂ ranging from 1.0 to 200.0 g/10 min as determined according to ISO 1133:1997 conditions M, at a temperature of 230°C and under a load of 2.16 kg, preferably ranging from 1.0 to 150.0 g/10 min, more preferably ranging

from 1.0 to 80.0 g/10 min, even more preferably ranging from 3.0 to 50.0 g/10 min, most preferably ranging from 5.0 to 30.0 g/10 min, or ranging from 6.0 to 25.0 g/10 min even most preferably ranging from 7.0 to 20.0 g/10 min, or ranging from 10.0 to 15.0 g/10 min, or ranging from 5.0 to 50.0 g/10 min.

- 5 When component B and/or component E contains two or more polypropylene resins of different melt index, the MI2 to be considered is the MI2 measured on the mixture of said two or more polypropylene resins.

Preferably, component B and/or component E has a density ranging from 0.870 to 0.946 g/cm³ as determined according to ISO 1183 at a temperature of 23°C, preferably ranging from 0.890
10 to 0.940 g/cm³; more preferably ranging from 0.900 to 0.930 g/cm³. The density is determined according to ISO 1183 at a temperature of 23 °C.

In an embodiment, component B and/or component E has a monomodal molecular weight distribution. In another embodiment, component B and/or component E has a multimodal molecular weight distribution, preferably a bimodal molecular weight distribution. Component
15 B and/or component E may be monomodal or multimodal.

As used herein, the terms “monomodal polypropylene” or “polypropylene with a monomodal molecular weight distribution” refer to polypropylene having one maximum in their molecular weight distribution curve, which is also defined as a unimodal distribution curve. As used herein, the terms “polypropylene with a bimodal molecular weight distribution” or “bimodal
20 polypropylene” refer to polypropylene having a distribution curve being the sum of two unimodal molecular weight distribution curves, and refer to a polypropylene product having two distinct but possibly overlapping populations of polypropylene macromolecules each having different weight average molecular weights.

As used herein, the terms “polypropylene with a multimodal molecular weight distribution” or
25 “multimodal polypropylene” refer to polypropylene with a distribution curve that is the sum of at least two, preferably more than two unimodal distribution curves, and refer to a polypropylene product having two or more distinct but possibly overlapping populations of polypropylene macromolecules each having different weight average molecular weights. The multimodal polypropylene can have an “apparent monomodal” molecular weight distribution,
30 which is a molecular weight distribution curve with a single peak and no shoulder. In an embodiment, said polypropylene resin having a multimodal, preferably bimodal, molecular weight distribution can be obtained by physically blending at least two polypropylene fractions.

Component B and/or component E comprises one or more polypropylenes selected from propylene homopolymers, copolymers of propylene and at least one comonomer, or mixture

thereof. Suitable comonomers comprise but are not limited to ethylene and aliphatic C₄-C₂₀ alpha-olefins. Examples of suitable aliphatic C₄-C₂₀ alpha-olefins include 1-butene, 1-pentene, 4-methyl-1-pentene, 1-hexene, 1-octene, 1-decene, 1-dodecene, 1-tetradecene, 1-hexadecene, 1-octadecene and 1-eicosene.

- 5 In a preferred embodiment of the disclosure, the Component B and/or component E is or comprise a homopolymer of propylene. A homopolymer according to this disclosure has less than 0.2 wt.%, preferably less than 0.1 wt.%, more preferably less than 0.05 wt.% and most preferably less than 0.005 wt.%, of alpha-olefins other than propylene in the polymer. Most preferred, no other alpha-olefins are detectable. Accordingly, when the polypropylene resin is
- 10 a homopolymer of propylene, the comonomer content in the polypropylene is less than 0.1 wt.%, preferably less than 0.05 wt.% and more preferably less than 0.005 wt.% based on the total weight of the polypropylene.

- In an embodiment component B, and/or component E, is or comprises a random copolymer of propylene and at least one comonomer. In such a case, component B and/or component E
- 15 comprises at least 0.1 wt.% of comonomer(s), preferably at least 1 wt.% based on the total weight of the random copolymer of propylene and at least one comonomer. With preference, it comprises up to 10 wt.% of comonomer(s) and most preferably up to 6 wt.%. Preferably, the random copolymers are copolymers of propylene and ethylene.

- In an embodiment, component B and/or component E is or comprises a heterophasic propylene copolymer resin. The heterophasic propylene copolymers comprise a matrix propylene polymer phase and a dispersed rubber phase. With preference, the rubber is ethylene propylene rubber.
- 20

- The content of component B in the polyolefin composition is at least 10 wt.% based on the total weight of the polyolefin composition, preferably at least 15 wt.% or at least 20 wt.%, more
- 25 preferably at least 25 wt.% or at least 27 wt.% or at least 30 wt.%, even more preferably at least 40 wt.%, most preferably at least 50 wt.%, and even most preferably at least 60 wt.%, or at least 70 wt.%.

- The content of component B in the polyolefin composition is at most 90 wt.% based on the total weight of the polyolefin composition, preferably at most 85 wt.% or at most 80 wt.%, more
- 30 preferably at most 75 wt.% or at most 70 wt.%, even more preferably at most 67 wt.% or at most 65 wt.% or at most 60 wt.%, most preferably at most 50 wt.%, and even most preferably at most 40 wt.%, or at most 30 wt.%.

The content of component E in the polyolefin composition is at least 10 wt.% based on the total weight of the polyolefin composition, preferably at least 15 wt.% or at least 20 wt.%, more preferably at least 25 wt.% or at least 27 wt.% or at least 30 wt.%, even more preferably at least 40 wt.%, most preferably at least 50 wt.%, and even most preferably at least 60 wt.%, or at least 70 wt.%.

The content of component E in the polyolefin composition is at most 90 wt.% based on the total weight of the polyolefin composition, preferably at most 85 wt.% or at most 80 wt.%, more preferably at most 75 wt.% or at most 70 wt.%, even more preferably at most 67 wt.% or at most 65 wt.% or at most 60 wt.%, most preferably at most 50 wt.%, and even most preferably at most 40 wt.%, or at most 30 wt.%.

An example of a commercially available propylene homopolymer suitable according to the disclosure is polypropylene:

- PPH 7060 (having an MI₂ of 12 g/10 min as determined by ISO 1133:1997 at 230 °C/ 2.16 kg and a density of 0.905 g/cm³ according to ISO 1183 at 23°C) marketed by TOTAL®.
- PPR 6288 (having an MI₂ of 8 g/10 min as determined by ISO 1133:1997 at 230 °C/ 2.16 kg and a density of 0.902 g/cm³ according to ISO 1183 at 23°C) marketed by TOTAL®.
- PPC 7712 (having an MI₂ of 13 g/10 min as determined by ISO 1133:1997 at 230 °C/ 2.16 kg and a density of 0.905 g/cm³ according to ISO 1183 at 23°C) marketed by TOTAL®.
- PPC 5660 (having an MI₂ of 7 g/10 min as determined by ISO 1133:1997 at 230 °C/ 2.16 kg and a density of 0.905 g/cm³ according to ISO 1183 at 23°C) marketed by TOTAL®.
- MR 2002 (having an MI₂ of 15 g/10 min as determined by ISO 1133:1997 at 230 °C/ 2.16 kg and a density of 0.905 g/cm³ according to ISO 1183 at 23°C) marketed by TOTAL®.

An example of a commercially available polypropylene post-consumer resin (PCR-PP), that can be used as component B (PCR_B) in the process according to the disclosure, is PP Regranulat 500-S or PP Regranulat 530-S both marketed by Vogt Plastic GmbH.

The polypropylene post-consumer resin (PCR-PP) that can be used in accordance with the disclosure is preferably originated from a specific collection of domestic or household waste, and/or from the end of life vehicles (ELV) waste.

In a preferred embodiment, the polypropylene recycled resin (rPP) that can be used in accordance with the disclosure comprises less than 10 wt.% based on the total weight of the recycled resin of polymers other than polypropylene. For example, the polypropylene recycled resin may contain up to 10 wt.% of polyethylene based on the total weight of the polypropylene recycled resin (rPP).

The use of a polypropylene recycled resin (rPP) as component B allows the increase of the total content of the recycled resins in the polyolefin composition.

The presence of component E in the polyolefin composition is optional. Component E comprises one or more polypropylenes and may be present when component D is a recycled resin selected from a polypropylene post-consumer resin (PCR-PP), a polypropylene post-industrial resin (PIR-PP), a polyolefin post-consumer resin (PCR-PO), a polyolefin post-industrial resin (PIR-PO) or a mixture thereof.

Selection of components A and/or B provided as polyolefin post-consumer resin

In an embodiment of the disclosure, the components A and B are provided together as a recycled polyolefin resin (rPO) selected from polyolefin post-consumer resin (PCR-PO) and/or polyolefin post-industrial resins (PIR-PO).

The polyolefin recycled resin (rPO) suitable for the disclosure comprises at least 30 wt.% of polyethylene based on the total weight of the polyolefin recycled resin and/or comprises at least 30 wt.% of polypropylene based on the total weight of the polyolefin recycled resin.

With preference, the polyolefin recycled resin (rPO) comprises at least 30 wt.% of polyethylene based on the total weight of the polyolefin recycled resin, preferably at least 40 wt.%, more preferably at least 50 wt.%, even more preferably at least 60 wt.%, and most preferably at least 70 wt.%

In an embodiment, the polyolefin recycled resin (rPO) comprises at least 30 wt.% of polypropylene based on the total weight of the polyolefin recycled resin, preferably at least 40 wt.%, more preferably at least 50 wt.%, even more preferably at least 60 wt.%, and most preferably at least 70 wt.%

Examples of polyolefin post-consumer resin (PCR-PO) are Regranulat 920-L and Regranulat 920-H both marketed by Vogt-plastic GmbH.

The total content recycled resin (RR_T) in the polyolefin composition is the sum of the content of the recycled resins in the composition. The total content of the recycle resin (wt.% RR_T) in the polyolefin composition is defined by the equation (1):

$$\text{wt.\% } RR_T = \text{wt.\% PCR-PP} + \text{wt.\% PCR-PE} + \text{wt.\% PCR-PO} + \text{wt.\% PIR-PP} + \text{wt.\% PIR-PE} + \text{wt.\% PIR-PO} \quad (1)$$

In an embodiment, the total content recycled resin (RR_T) in the polyolefin composition is at least 40 wt.% based on the total weight of the polyolefin composition, preferably at least 42 wt.%, more preferably at least 45 wt.%, even more preferably at least 50 wt.% and most preferably at least 52 wt.%, at least 60 wt.% or at least 70 wt.%. With preference, the total content of the recycled resin (RR_T) in the polyolefin composition ranges from 50 to 99 wt.% based on the total weight of the polyolefin composition.

Selection of the coupling agent (Component C)

The disclosure provides the addition of a coupling agent (component C) to the polyolefin composition wherein the content of component C preferably ranges from 0.5 to 15 wt.% based on the total weight of the polyolefin composition, more preferably from 0.6 to 10.0 wt.%, even more preferably from 0.7 wt.% to 8.0 wt.%, most preferably from 0.8 wt.% to 7.0 wt.%, even most preferably from 0.9 wt.% to 6.0 wt.%, or from 1.0 wt.% to 5.0 wt.

According to the disclosure, component C is selected from:

- one or more diol functionalized polymers; and/or
- one or more metallic salts.

In accordance with the disclosure, when component C is or comprises one or more diol functionalized polymers; and/or one or more metallic salts; it is preferable to perform a first step of hydrolysis of the anhydride function of the component H before blending said component C to the other component to produce the polyolefin composition. The hydrolysis of the anhydride function of the component H can be made by the addition of water into the blend.

When component C is or comprises one or more diol functionalized polymers, it is preferably selected from polybutadiene diol, poly farnesene diol and polylactic acid diol; more preferably component C is or comprises polybutadiene diol. A commercially available polybutadiene diol suitable for the disclosure is Krasol from Cray valley.

When component C is or comprises one or more metallic salts; it is preferably selected from zinc stearate, zinc acetate, sodium hydroxide and/or potassium hydroxide. With preference, component C is or comprises potassium hydroxide.

For example, component C comprises one or more metallic salts and the content of the one or more metallic salts ranges from 0.5 to 10 wt.% based on the total weight of the polyolefin composition, preferably from 0.6 to 8.0 wt.%, more preferably from 0.7 wt.% to 5.0 wt.%, even more preferably from 0.8 wt.% to 4.0 wt.%, most preferably from 0.9 wt.% to 3.0 wt.%, even most preferably from 1.0 wt.% to 2.0 wt.

For example, component C comprises one or more metallic salts and the content of the one or more metallic salts ranges from 0.5 to 1.5 wt.% based on the total weight of the polyolefin composition, preferably from 0.6 to 1.0 wt.%, more preferably from 0.7 wt.% to 0.9 wt.%.

For example, component C comprises potassium hydroxide in a content of at least 0.5 wt.% based on the total weight of the polyolefin composition; with preference, at least 0.8 wt.%, or at least 1.0 wt.%.

For example, component C comprises potassium hydroxide in a content of at most 2.0 wt.% based on the total weight of the polyolefin composition; with preference, at most 1.5 wt.% or at most 1.2 wt.% or at most 1.0 wt.%.

For examples, component C comprises potassium hydroxide in a content of at least 50 wt.% based on the total weight of component C; preferably at least 75 wt.%, more preferably 100 wt.%.

Selection of the acid-grafted polyolefin and/or of the anhydride-modified polyolefin (Component H)

In an embodiment, component H is one or more grafted and/or modified polyolefins selected from acid-grafted polypropylene, acid-grafted polyethylene, anhydride-modified polypropylene, and anhydride-modified polyethylene.

With preference, component H is one or more grafted and/or modified polyolefins selected from acrylic acid-grafted polyolefin, fumaric acid-grafted polyolefin, maleic acid-grafted polyolefin, methacrylic acid-grafted polyolefin, nadic acid-grafted polyolefin, citraconic acid-grafted polyolefin, itaconic acid-grafted polyolefin, acrylic anhydride-modified polyolefin, fumaric anhydride-modified polyolefin, maleic anhydride-modified polyolefin, methacrylic anhydride-modified polyolefin, nadic anhydride-modified polyolefin, citraconic anhydride-modified polyolefin, itaconic anhydride-modified polyolefin; wherein the polyolefin is selected from polyethylene and/or polypropylene.

In other words, component H is one or more grafted and/or modified polyolefins selected from acrylic acid-grafted polyethylene, fumaric acid-grafted polyethylene, maleic acid-grafted

polyethylene, methacrylic acid-grafted polyethylene, nadic acid-grafted polyethylene, citraconic acid-grafted polyethylene, itaconic acid-grafted polyethylene, acrylic anhydride modified polyethylene, fumaric anhydride modified polyethylene, maleic anhydride-modified polyethylene, methacrylic anhydride modified polyethylene, nadic anhydride modified polyethylene, citraconic anhydride modified polyethylene, itaconic anhydride modified polyethylene, acrylic acid-grafted polypropylene, fumaric acid-grafted polypropylene, maleic acid-grafted polypropylene, methacrylic acid-grafted polypropylene, nadic acid-grafted polypropylene, citraconic acid-grafted polypropylene, itaconic acid-grafted polypropylene, acrylic anhydride modified polypropylene, fumaric anhydride modified polypropylene, maleic anhydride-modified polypropylene, methacrylic anhydride modified polypropylene, nadic anhydride modified polypropylene, citraconic anhydride modified polypropylene, itaconic anhydride-modified polypropylene.

In a preferred embodiment, component H is one or more maleic anhydride-modified polyolefins selected from one or more maleic anhydride-modified polyethylenes and/or one or more maleic anhydride-modified polypropylenes.

The component H can be grafted or modified *in situ* or provided in the form of a commercial product already acid-grafted or anhydride-modified.

In an embodiment, the content of component H ranges from 0.5 to 15 wt.% based on the total weight of the polyolefin composition, preferably from 0.6 to 10.0 wt.%, more preferably from 0.7 wt.% to 8.0 wt.%, even more preferably from 0.8 wt.% to 7.0 wt.%, most preferably from 0.9 wt.% to 6.0 wt.%, even most preferably from 1.0 wt.% to 5.0 wt.

In an embodiment, component H has a weight average molecular weight (M_w) of at least 10,000 g/mol, preferably at least 12,000 g/mol, more preferably at least 15,000 g/mol, even more preferably at least 20,000 g/mol, most preferably at least 30,000 g/mol, or at least 40,000 g/mol, or at least 45,000 g/mol, or at least 50,000 g/mol, or at least 55,000 g/mol, or at least 60,000 g/mol.

In an embodiment, component H has a number average molecular weight (M_n) of at least 2,400 g/mol, more preferably at least 2,500 g/mol, even more preferably at least 3,000 g/mol, most preferably at least 5,000 g/mol, even most preferably at least 8,000 g/mol, or at least 10,000 g/mol, or at least 12,000 g/mol, or at least 13,000 g/mol, or at least 15,000 g/mol.

More preferably component H has a weight average molecular weight (M_w) of at least 10,000 g/mol and/or a number average molecular weight (M_n) of at least 2,400 g/mol.

Selection of the filler (component F)

In a preferred embodiment, in order to enhance the mechanical properties, the process further comprises the step of providing a component F being a filler and the step of melt-blending the components to form a polyolefin composition comprises melt-blending the component F with the other components to form the polyolefin composition.

The component F is preferably selected from talc mineral filler, wollastonite, calcium carbonate, modified calcium carbonate, coated calcium carbonate, glass fibres, bamboo fibres, flax fibres, hemp fibres, carbon black, carbon nanotubes, graphene nanotubes, and any mixture thereof; more preferably component F is selected from glass fibres and carbon nanotubes.

Examples of talc that can be used as component F of the present disclosure is talc filler Finntalc MO5SL and Finntalc M15, both manufactured and sold by Mondo Minerals (CAS-No. 14807-96-6. Both are considered to be standard talc in the context of the disclosure. Finntalc MO5SL has a median particle size (d50) of 2.2 µm. Finntalc M15 has a median particle size (d50) of 4.5 µm.

Examples of carbon-nanotubes commercially available that can be used in the context of the disclosure are NC7000 marketed by Nanocyl.

The content of component F ranges from 0 to 50 wt.% based on the total weight of the polyolefin composition; preferably from 0.1 to 50.0 wt.%, more preferably from 0.2 wt.% to 40.0 wt.%, even more preferably from 0.5 wt.% to 30.0 wt.%, most preferably from 1.0 wt.% to 20 wt.%, even most preferably from 1.5 wt.% to 15.0 wt.%, or from 2.5 wt.% to 12.5 wt.%, or from 5.0 wt.% to 10.0 wt.%.

In an embodiment, the polyolefin composition comprises at least 0.1 wt.% of component F, based on the total weight of the polyolefin composition, preferably at least 0.5 wt.%, more preferably at least 1.0 wt.%, even more preferably of at least 1.5 wt.%, most preferably at least 2.5 wt.% and even most preferably at least 5.0 wt.%.

With preference, the polyolefin composition comprises at most 40.0 wt.% of component F, based on the total weight of the polyolefin composition, preferably at most 30 wt.%, more preferably at most 20 wt.%, even more preferably at most 15 wt.%, most preferably at most 12.5 wt.% or at most 10.0 wt.%.

Selection of the elastomer (component G)

In a preferred embodiment, in order to enhance the impact properties, the process further comprises the step of providing a component G being one or more elastomers and the step of melt-blending the components to form a polyolefin composition comprises melt-blending the component G with the other components to form the polyolefin composition.

- 5 The component G, when present, is preferably selected from copolymers of ethylene with a C₃-C₁₀ α-olefin containing at least 20 wt. %, preferably from 20 to 70 wt. %, of C₃-C₁₀ α-olefin (determined by ¹³C-NMR analysis). Suitable and preferred copolymers commercially available are obtained with metallocene or constrained geometry catalysis and typically have molecular weight distribution (Mw/Mn measured via GPC) ranging from 1 to 3.
- 10 With preference, component G is selected from elastomeric copolymers of ethylene with 1-octene, elastomeric copolymers of ethylene with 1-butene and any mixture thereof.

For example, component G is selected from:

- elastomeric copolymers of ethylene with 1-octene having from 20 wt. % to 45 wt. % of 1-octene (determined by ¹³C-NMR analysis); and/or
- 15 - elastomeric thermoplastic copolymers of ethylene with 1-butene having from 20 wt. % to 40 wt. % of 1-butene (determined by ¹³C-NMR analysis); and/or
- elastomeric thermoplastic copolymers of ethylene with propylene.

Non-exhaustive specific examples of elastomers that can be used in the process according to the disclosure are:

- 20 a) an ethylene-butene-1 random copolymer rubber such as:
- ENGAGE 7642 produced by The Dow Chemical Co. Ltd., having an MI2 of 0.5 g/10 min.
 - ENGAGE 7447 produced by The Dow Chemical Co. Ltd., having an MI2 of 5.0 g/10 min.
 - ENGAGE 7467 produced by The Dow Chemical Co. Ltd., having an MI2 of 1.2 g/10 min.
 - Tafmer A0550S from Mitsui having an MI2 of 0.5 g/10 min.
 - 25 - Tafmer A1550S from Mitsui having an MI2 of 1.0 g/10 min.
 - Lucene 168 from LG having an MI2 of 1.2 g/10 min.
- b) an ethylene-octene-1 random copolymer rubber such as:
- Affinity EG8100 from The Dow Chemical Co. Ltd., having an MI2 of 1.0 g/10 min.
 - Affinity EG8150 from The Dow Chemical Co. Ltd., having an MI2 of 0.5 g/10 min.
- 30 c) an ethylene-propylene copolymer rubber such as:
- Exxon IT0316 from ExxonMobil, having an ethylene content of 16 wt.%.

For the cited elastomers, the MI2 was determined according to ISO 1133:1997 (190 °C /2.16 Kg).

In an embodiment, alternative or cumulative, the composition further comprises from 0.1 to 15 wt.%, based on the total weight of the polyolefin composition of one or more styrene-based thermoplastic elastomers (TPE-S) selected from SIS (Styrene isoprene styrene block copolymers), SEPS (Hydrogenated styrene isoprene styrene block copolymers), SBS (Styrene butadiene styrene block copolymers), SEBS (Hydrogenated styrenic butadiene copolymers), SBSS (Styrene butadiene styrene styrene block copolymers), and any mixture thereof.

Preferably, the polyolefin composition comprises at least 0.1 wt.% of component G, based on the total weight of the polyolefin composition, preferably at least 0.5 wt.%, more preferably at least 1.0 wt.%, even more preferably of at least 1.5 wt.%, most preferably at least 2.5 wt.% and even most preferably at least 5.0 wt.%.

With preference, the polyolefin composition comprises at most 9.8 wt.% of component G, based on the total weight of the polyolefin composition, preferably at most 9.5 wt.%, more preferably at most 9.3 wt.%, even more preferably at most 9.1 wt.%, most preferably at most 9.0 wt.%, and even most preferably at most 8.5 wt.%.

In a preferred embodiment, the content of component G ranges from 0 to 10 wt.% based on the total weight of the polyolefin composition; preferably from 0.1 to 10.0 wt.%, more preferably from 0.2 wt.% to 9.8 wt.%, even more preferably from 0.5 wt.% to 9.5 wt.%, most preferably from 1.0 wt.% to 9.3 wt.%, even most preferably from 1.5 wt.% to 9.1 wt.%, or from 2.5 wt.% to 9.0 wt.%, or from 5.0 wt.% to 8.5 wt.%.

Component G has an MI₂ ranging from 0.5 to 5.0 g/10 min as determined according to ISO 1133:1997 conditions D, at a temperature of 190 °C and under a load of 2.16 kg.

With preference, component G has an MI₂ of at most 4.5 g/10 min as determined according to ISO 1133:1997 conditions D, at a temperature of 190 °C and under a load of 2.16 kg, preferably of at most 4.0 g/10 min, more preferably of at most 3.5 g/10 min, even more preferably of at most 3.0 g/10 min, most preferably of at most 2.5 g/10 min and even most preferably of at most 2.0 g/10 min.

TEST METHODS

The melt index (MI₂) of polypropylene and polypropylene compositions is determined according to the method of standard ISO 1133:1997, conditions M, at a temperature of 230 °C and under a load of 2.16 kg using a die of 2.096 mm.

The melt index (MI2) of polyethylene and polyethylene compositions is determined according to the method of standard ISO 1133:1997, conditions D, at a temperature of 190 °C and under a load of 2.16 kg using a die of 2.096 mm.

5 The density of polyethylene and polyethylene compositions is measured according to the method of standard ISO 1183 at a temperature of 23 °C.

The molecular weight Mn (number average molecular weight), Mw (weight average molecular weight), Mz (z average molecular weight) and molecular weight distribution D (Mw/Mn) and D' (Mz/Mw) are determined by size exclusion chromatography (SEC) and in particular by gel permeation chromatography (GPC). Briefly, a GPC-IR5 from Polymer Char was used: 10 mg
10 polypropylene sample is dissolved at 160 °C in 10 mL of trichlorobenzene (technical grade) for 1 hour. Analytical conditions for the GPC-IR from Polymer Char are:

- Injection volume: +/- 0.4 mL;
- Automatic sample preparation and injector temperature: 160 °C;
- Column temperature: 145 °C;
- 15 - Detector temperature: 160 °C;
- Column set: 2 Shodex AT-806MS and 1 Styragel HT6E;
- Flow rate: 1 mL/min;
- Detector: IR5 Infrared detector (2800-3000 cm⁻¹);
- Calibration: Narrow standards of polystyrene (commercially available);
- 20 - Calculation for polypropylene: Based on Mark-Houwink relation ($\log_{10}(M_{PP}) = \log_{10}(M_{PS}) - 0,25323$); cut off on the low molecular weight end at $M_{PP} = 1000$;
- Calculation for polyethylene: Based on Mark-Houwink relation ($\log_{10}(M_{PE}) = 0.965909 \times \log_{10}(M_{PS}) - 0,28264$); cut off on the low molecular weight end at $M_{PE} = 1000$.

The molecular weight averages used in establishing molecular weight/property relationships
25 are the number average (M_n), weight average (M_w) and z average (M_z) molecular weight. These averages are defined by the following expressions and are determined from the calculated M_i :

$$M_n = \frac{\sum_i N_i M_i}{\sum_i N_i} = \frac{\sum_i W_i}{\sum_i W_i / M_i} = \frac{\sum_i h_i}{\sum_i h_i / M_i}$$

$$M_w = \frac{\sum_i N_i M_i^2}{\sum_i N_i M_i} = \frac{\sum_i W_i M_i}{\sum_i W_i} = \frac{\sum_i h_i M_i}{\sum_i h_i}$$

$$M_z = \frac{\sum_i N_i M_i^3}{\sum_i N_i M_i^2} = \frac{\sum_i W_i M_i^2}{\sum_i W_i M_i} = \frac{\sum_i h_i M_i^2}{\sum_i h_i M_i}$$

5

Here N_i and W_i are the number and weight, respectively, of molecules having molecular weight M_i . The third representation in each case (farthest right) defines how one obtains these averages from SEC chromatograms. h_i is the height (from baseline) of the SEC curve at the i_{th} elution fraction and M_i is the molecular weight of species eluting at this increment.

10 The molecular weight distribution (MWD) is then calculated as M_w/M_n .

The comonomer content of polypropylene is determined by ^{13}C -NMR analysis of pellets according to the method described by G.J. Ray et al. in *Macromolecules*, vol. 10, n° 4, 1977, p. 773-778.

15 The ^{13}C -NMR analysis is performed using a 400 MHz or 500 MHz Bruker NMR spectrometer under conditions such that the signal intensity in the spectrum is directly proportional to the total number of contributing carbon atoms in the sample. Such conditions are well known to the person skilled in the art and include for example sufficient relaxation time, etc. In practice, the intensity of a signal is obtained from its integral, i.e. the corresponding area. The data is acquired using proton decoupling, 2000 to 4000 scans per spectrum with 10 mm at room

20 temperature through or 240 scans per spectrum with a 10 mm cryoprobe, a pulse repetition delay of 11 seconds and a spectral width of 25000 Hz (+/- 3000 Hz). The sample is prepared by dissolving a sufficient amount of polymer in 1,2,4-trichlorobenzene (TCB, 99%, spectroscopic grade) at 130 °C and occasional agitation to homogenise the sample, followed by the addition of hexadeuterobenzene (C_6D_6 , spectroscopic grade) and a minor amount of

25 hexamethyldisiloxane (HMDS, 99.5+ %), with HMDS serving as internal standard. To give an example, about 200 mg to 600 mg of polymer is dissolved in 2.0 mL of TCB, followed by addition of 0.5 mL of C_6D_6 and 2 to 3 drops of HMDS.

Following data acquisition, the chemical shifts are referenced to the signal of the internal standard HMDS, which is assigned a value of 2.03 ppm.

The Charpy impact strength (notched) at 23 °C was determined according to ISO 179.

The Izod impact strength (notched) at 23 °C and at -20 °C was determined according to ISO 180.

The mechanical properties such as the tensile modulus, the strength at break, the strength at yield, the elongation at yield and elongation at break were determined according to ISO 527 1B/1A. The properties were tested at 23 °C.

Elastic modulus is obtained during a tensile strength test. It is the slope of the line between 0.05 and 0.25 % deformation.

The following non-limiting examples illustrate the disclosure.

EXAMPLES

Example 1: production of PP/PE blends without hydrolysis of the maleic anhydride functions

Grafting of the polyolefins was done in a previous step.

The polyethylene PE1 used was a maleic anhydride grafted linear low-density polyethylene (LLDPE) named OREVAC 18334 (commercially available from Arkema). OREVAC 18334 has an MI2 of 1.0 g/10 min (ISO1133, 2.16 kg, 190°C) and a density of 0.920 g/cm³ (ISO1183).

The polypropylene PP1 used was a maleic anhydride propylene homopolymer named OREVAC 18729 (commercially available from Arkema). OREVAC 18729 has an MI2 of 4.5 g/10 min (ISO1133, 2.16 kg, 230°C) and a density of 0.900 g/cm³ (ISO1183).

The coupling agents (component C) were selected from:

- A polybutadiene diol commercially available from Cray Valley under the trademark KRASOL
- Metallic salts, KOH and ZnSt commercially available from Sigma.

Preparation of the blends.

An internal kneader/mixer Brabender was used to preparing all PE/PP/coupling agent blends. It is equipped with two counter-rotative blades. The software Winmix enabled the recording of the torque and temperature values during the test. The mixing was carried out at 200°C for 10

minutes, with a rotation speed of 100 rpm. 40 grams of matters were introduced at the beginning of the test, and 30 to 35 g were collected in the end after cleaning. If the coupling agent for the mix was solid, it was introduced with the pellets at the beginning of the test. If it was liquid, it was introduced after all the matter melted and started to be mixed at around 1 to 2 minutes.

The results have been reported on table 1 for blends comprising a majority of PE and in table 2 for blends comprising a majority of PP.

To ease the comparison, the properties of the reference blend without a coupling agent is added.

10 Table 1: Properties of the blends

	Sample 1	Sample 2	Sample 3	Sample 4
PE1 (wt.%)	70	69	69	69
PP1 (wt.%)	30	30	30	30
Diol (wt.%)	-	1	-	-
ZnSt (wt.%)	-	-	1	-
KOH (wt.%)	-	-	-	1
Tensile Mod (MPa)	422,6 (10)	415,6 (10)	418,9 (18)	422,4 (8)
Strength at yield (MPa)	14.8 (0.28)	16 (0,35)	15,1 (1,07)	17,2 (0,42)
Elongation at yield (%)	48.4 (2.57)	53 (7,2)	50,9 (11,1)	62,3 (1,46)
Strength at break (MPa)	20.2 (2.80)	17,3 (5,4)	14,4 (3,9)	21,9 (2,7)
Elongation at break (%)	385 (92.5)	267 (179)	273,9 (51)	386,3 (114,5)
Notched Izod (KJ/m ²)	48.81 (7.76)	52,0 (0,61)	48,57 (1,1)	52,03 (2,83)
Rupture type	partial	partial	partial	partial

From the results, it can be seen that only the impact properties were slightly improved by the addition of the coupling agents.

Table 2: Properties of the blends

	Sample 5	Sample 6	Sample 7	Sample 8
PE1 (wt.%)	30	30	30	30
PP1 (wt.%)	70	69	69	69
Diol (wt.%)	-	1	-	-
ZnSt (wt.%)	-	-	1	-
KOH (wt.%)	-	-	-	1
Tensile Mod (MPa)	944,5 (10)	871,2 (35)	772 (10)	941,3 (23)

Strength at yield (MPa)	22,7 (0,31)	21,8 (0,6)	19,7 (0,34)	25 (0,41)
Elongation at yield (%)	13,1 (0,30)	14,6 (0,12)	13,4 (0,48)	19,3 (1,01)
Strength at break (MPa)	32,2 (4,8)	29,3 (2,6)	25,3 (3,05)	27 (4,08)
Elongation at break (%)	594,7 (118,4)	537,7 (92,7)	569,8 (136,1)	320,6 (147)
Notched Izod (KJ/m ²)	7,44 (0,17)	12,78 (1,17)	5,49 (0,81)	23,71 (1,97)
Rupture type	Hinge	Hinge	Hinge	Hinge

From the results, it can be seen that only the impact properties were slightly improved by the addition of the coupling agents, except with KOH that provides a significant improvement in impact properties.

5 **Example 2: production of PP/PE blends with the hydrolysis of the maleic anhydride functions**

Further tests have been conducted according to the same processing conditions than in Example 1, except that water was added in order to hydrolyse the maleic anhydride functions to form maleic acids. Around 2.5 wt. % of water was added to the mix Brabender mixing, 1 min after the grafted polyolefin introduction. The coupling agents were added only after hydrolysis between 2 min and 30 sec. The added water content is added in addition to the composition wherein the total weight of the composition is determined without the water.

The results have been reported in Table 3 for blends comprising a majority of PE and in Table 4 for blends comprising a majority of PP.

15 To ease the comparison, the properties of the reference blend without a coupling agent is added.

Table 3: Properties of the blends

	Sample 9	Sample 10	Sample 11	Sample 12
PE1 (wt. %)	70	69	69	69
PP1 (wt. %)	30	30	30	30
Water (wt. %)	2.5	2.5	2.5	2.5
Diol (wt. %)	-	1	-	-
ZnSt (wt. %)	-	-	1	-
KOH (wt. %)	-	-	-	1
Tensile Mod (MPa)	460,3 (2)	413,3 (14)	420,1 (10)	393,4 (2)
Strength at yield (MPa)	16,9 (0,19)	15,7 (0,64)	14,5 (0,23)	17 (0,29)
Elongation at yield (%)	42,7 (1,70)	43,3 (2,08)	28,1 (4,9)	67,7 (3,64)

Strength at break (MPa)	17,8 (3,7)	20 (2,75)	21,5 (1,7)	25 (2,28)
Elongation at break (%)	277,2 (31)	390,9 (110,3)	504,2 (62,6)	477,4 (88,9)
Notched Izod (KJ/m ²)	51,43 (0,58)	51,16 (0,58)	48,87 (3,42)	47,25 (12,27)
Rupture type	partial	partial	partial	partial

From the results, it can be seen that the impact properties were not improved by the addition of the coupling agents. Elongation at break was highly improved by all coupling agents.

Table 4: Properties of the blends

	Sample 13	Sample 14	Sample 15	Sample 16
PE1 (wt.%)	30	30	30	30
PP1 (wt.%)	70	69	69	69
Water (wt. %)	2.5	2.5	2.5	2.5
Diol (wt.%)	-	1	-	-
ZnSt (wt.%)	-	-	1	-
KOH (wt.%)	-	-	-	1
Tensile Mod (MPa)	931 (21)	862 (20)	801,7 (19)	880 (24)
Strength at yield (MPa)	22,9 (0,56)	21,7 (0,13)	20,6 (0,36)	24 (0,44)
Elongation at yield (%)	12,6 (0,57)	13,9 (1,08)	13,6 (0,65)	16,8 (0,86)
Strength at break (MPa)	29,2 (8,1)	34,9 (3,2)	27,4 (6,3)	34,7 (2,37)
Elongation at break (%)	506,7 (196)	724,7 (113,8)	662,8 (94)	540,3 (115,7)
Notched Izod (KJ/m ²)	12,03 (0,56)	11,28 (0,44)	7,17 (2,01)	20,58 (3,27)
Rupture type	Hinge	Hinge	Hinge	Hinge

5

From the results, it can be seen that the impact properties were only slightly improved by the addition of the coupling agents, except for KOH wherein an important improvement was found. Elongation at break was highly improved by all coupling agents. The results regarding elongation at break in sample 16 can be improved by lowering the content of KOH added to the composition.

10

CLAIMS

1. A process to produce a polyolefin composition comprising a blend of polyethylene and polypropylene characterized in that it comprises the steps of:
 - 5 - providing from 10 to 90 wt.% based on the total weight of the polyolefin composition of a component A, wherein component A is one or more polyethylenes;
 - providing from 10 to 90 wt.% based on the total weight of the polyolefin composition of a component B, wherein component B is one or more polypropylenes;
 - 10 - providing a component H, wherein component H is one or more grafted and/or modified polyolefins selected from acid-grafted polyolefins and/or anhydride-modified polyolefins; wherein the polyolefin is selected from polyethylene and/or polypropylene;
 - 15 - melt-blending the components to form an intermediate polyolefin composition comprising acid-grafted polyolefin and/or anhydride-modified polyolefin;
 - providing a component C, wherein component C is one or more coupling agents selected from one or more diol functionalized polymers and/or one or more metallic salts;
 - 20 - melt-blending the intermediate polyolefin composition with component C to form a polyolefin composition.
2. The process according to claim 1, characterized in that component H is or comprises anhydride-modified polyolefin; wherein the polyolefin is selected from polyethylene and/or polypropylene, and in that the process further comprises:
 - 25 - a step of providing water; and
 - a step of melt-blending the components to form an intermediate polyolefin composition comprising anhydride-modified polyolefin wherein at least a part of the anhydride functions is hydrolyzed;
 - 30 wherein the steps of providing water and of forming the intermediate polyolefin composition are conducted before the step of providing the component C.
3. The process according to any one of claims 1 to 2, characterized in that:
 - 35 - component C comprises one or more metallic salts selected from zinc stearate, zinc acetate, sodium hydroxide and/or potassium hydroxide; with preference, component C is or comprises potassium hydroxide; and/or

- component C comprises one or more diol functionalized polymers selected from polybutadiene diol, poly farnesene diol, and polylactic acid diol; with preference, component C is or comprises polybutadiene diol.

5 4. The process according to any one of claims 1 to 3, characterized in that:

- component C comprises potassium hydroxide in a content of at least 0.5 wt.% based on the total weight of the polyolefin composition; with preference, at least 0.8 wt.%; and/or
- component C comprises potassium hydroxide in a content of at least 50 wt.%
10 based on the total weight of component C; preferably at least 75 wt.%, more preferably 100 wt.%.

5 5. The process according to any one of claims 1 to 4, characterized in that component C comprises potassium hydroxide and the content of component B is at least 50 wt.%
15 based on the total weight of the polyolefin composition; with preference, at least 60 wt.%.

6. The process according to any one of claims 1 to 5, characterized in that:

- the content of component C ranges from 0.5 to 15 wt.% based on the total weight
20 of the polyolefin composition; and/or
- the content of component H ranges from 0.5 to 15 wt.% based on the total weight of the polyolefin composition; and/or
- the total content of both component C and component H ranges from 1 to 30 wt.% based on the total weight of the polyolefin composition; with preference from 5 to
25 10 wt.%.

7. The process according to any one of claims 2 to 6, characterized in that

- component H is one or more maleic anhydride-modified polyolefins selected from one or more maleic anhydride-modified polyethylenes and/or one or more
30 maleic anhydride-modified polypropylenes; and/or,
- the content of water ranges from 0.1 to 10.0 wt.% based on the total weight of the polyolefin composition without water; preferably 0.5 to 5.0 wt.%, more preferably from 1.0 to 3.0 wt.%; and/or
- component H has a weight average molecular weight (Mw) of at least 10,000
35 g/mol and/or a number average molecular weight (Mn) of at least 2,400 g/mol.

8. The process according to any one of claims 1 to 7, characterized in that:

- the content of component A ranges from 15 to 85 wt.% based on the total weight of the polyolefin composition, with preference from 20 to 80 wt.%, or from 25 wt.% to 75 wt.%; and/or
- component A has an MI₂ ranging from 0.10 to 70.0 g/10 min as determined according to ISO 1133:1997 conditions D, at a temperature of 190°C and under a load of 2.16 kg.

9. The process according to any one of claims 1 to 8, characterized in that:

- the content of component B ranges from 15 to 85 wt.% based on the total weight of the polyolefin composition, with preference from 20 to 80 wt.%, or from 25 wt.% to 75 wt.%; and/or
- component B has an MI₂ ranging from 1.0 to 200.0 g/10 min as determined according to ISO 1133:1997 conditions M, at a temperature of 230°C and under a load of 2.16 kg; and/or
- the component A and the component B are in a weight ratio ranging between 2:1 to 1:2.

10. The process according to any one of claim 1 to 9, characterized in that the component A and/or the component B are recycled resins selected from post-consumer resins (PCR) and/or post-industrial resins (PIR); with preference:

- the total content of the recycled resins (RR_T) in the polyolefin composition ranges from 50 to 99 wt.% based on the total weight of the polyolefin composition; and/or
- the components A and B are provided separately as a polyethylene recycled resin (rPE), and a polypropylene recycled resin (rPP); and/or
- both components A and B are recycled resins, and in that, before the step of melt blending the components to form an intermediate polyolefin composition, the process further comprises a step of providing a component D being at least one virgin polyethylene and/or a component E being at least one virgin polypropylene.

11. The process according to any one of claims from 1 to 10, characterized in that, before the step of melt blending the components to form a polyolefin composition, the process further comprises a step of providing a component F being one or more fillers; and/or the process further comprises a step of providing a component G being one or more elastomers.

12. A polyolefin composition characterized in that it comprises

- from 10 to 90 wt.% based on the total weight of the polyolefin composition of a component A being of one or more polyethylenes;
- from 10 to 90 wt.% based on the total weight of the polyolefin composition of a component B being one or more polypropylenes;
- a component C, being one or more coupling agents selected from one or more diol functionalized polymers and/or one or more metallic salts; and
- a component H being one or more grafted and/or modified polyolefins selected from acid-grafted polyolefins and/or anhydride-modified polyolefins; wherein the polyolefin is selected from polyethylene and/or polypropylene;

more preferably the polyolefin composition is produced by a process according to any one of claims 1 to 11.

13. The polyolefin composition of claim 12, characterized in that component C comprises at least 50 wt.% based on the total weight of component C of potassium hydroxide; preferably at least 75 wt.%, more preferably 100 wt.%.

14. Use of the polyolefin composition obtained by the process according to any one of claims 1 to 11, or of the polyolefin composition of claim 12 or 13, to make an article in a process selected from 3D-printing, extrusion, blow-moulding, injection, injection blow moulding, injection stretch blow moulding, rotomoulding, extrusion and thermoforming.

15. An article made from the polyolefin composition obtained by the process according to any one of claims 1 to 11, or by the polyolefin composition of claim 12 or 13, preferably:

- the article is a thermoformed article or a moulded article selected from injection moulded article, compression moulded article, rotomoulded article, injection blow moulded article, and injection stretch blow moulded article, and/or
- the article is selected from the group consisting of automobile parts, non-food packaging, retort packaging, housewares, caps, closures, media packaging and medical devices.

16. The use of a component C being one or more coupling agents in a polyolefin composition comprising a component A being of one or more polyethylenes, a component B being one or more polypropylenes and a component H being one or more grafted and/or modified polyolefins selected from acid-grafted polyolefins and/or anhydride-modified polyolefins; wherein the polyolefin is selected from polyethylene and/or polypropylene; wherein the component C is selected from one or more diol functionalized polymers; and/or one or more metallic salts; wherein the use comprises

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- the hydrolysis of the anhydride functions when present to form an intermediate polyolefin composition before the addition of the coupling agent to form the polyolefin composition; and/or
- the coupling agent comprising potassium hydroxide and the content of component B is at least 50 wt.% based on the total weight of the polyolefin composition.

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2020/054148A. CLASSIFICATION OF SUBJECT MATTER
INV. C08L23/04
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C08L

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

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

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	CN 106 243 508 A (SHANDONG SANLING AUTOMOBILE INTERIOR CO LTD) 21 December 2016 (2016-12-21) examples 1-3 -----	1-16



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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Patent document cited in search report	Publication date	Patent family member(s)	Publication date
CN 106243508	A	21-12-2016	NONE
