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HETEROPHASIC PROPYLENE COPOLYMER (HECO) COMPOSITION
HAVING EXCELLENT IMPACT STRENGTH, STIFFNESS AND PROCESSABILITY

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The present invention relates to a heterophasic propylene copolymer (HECO) composition, an article comprising the heterophasic propylene copolymer (HECO) composition, preferably a molded article like an injection molded article or a compression molded article, such as parts of car seats, paint pails, strollers, baby walkers, toys, heavy duty pails or transport

25 packagings, as well as the use of the heterophasic propylene copolymer (HECO) composition for the preparation of such an article.

Heterophasic propylene copolymers are widely used for the preparation of moulded articles such as injection moulded articles. Typically, producers of such articles are looking for better

30 stiffness, impact strength combined with a better processability. The balance between stiffness, processability and impact strength is often delicate as high impact strength leads to a significant reduction of stiffness and processability and vice versa. However, it is of high importance that both stiffness and impact strength remain on a high level.

35 Accordingly, there is a need in the art for heterophasic propylene copolymer (HECO) compositions featuring excellent impact properties and stiffness. Said heterophasic propylene copolymer (HECO) compositions should have a good processability as well.

Therefore, it is an object of the present invention to provide a heterophasic propylene copolymer (HECO) composition having an improved impact strength, both at room and low temperature, while the stiffness and melt flow rate remain on a high level.

- 5 The foregoing and other objectives are solved by the subject-matter of the present invention. Advantageous embodiments of the inventive polypropylene composition are defined in the corresponding sub-claims.

Accordingly, the present invention is directed to a heterophasic propylene copolymer
10 (HECO) composition comprising

- a) a matrix being a propylene polymer (M), which is optionally at least bimodal, and
- b) an elastomeric ethylene-propylene copolymer (E) being dispersed in said matrix, the elastomeric ethylene-propylene copolymer (E) has an intrinsic
15 viscosity (IV) in the range from 3.3 to 5.0 dl/g and an ethylene content in the range from 34 to 60 wt.% based on the total weight of the elastomeric ethylene-propylene copolymer (E),

wherein the xylene cold soluble fraction (XCS) is in the range from 25.0 to 50.0 wt.-%, based on the total weight of the composition.

20 According to one embodiment of the present invention, the heterophasic propylene copolymer (HECO) composition has

- i) a melt flow rate MFR_2 (230°C, 2.16 kg) determined according to ISO 1133 in the range of 10 to 30 g/10min, preferably 12 to 18 g/10 min, and/or
- 25 ii) a flexural modulus measured according to ISO 178 on injection molded specimen of 1000 to 1400 MPa, preferably from 1050 to 1250 MPa, and/or
- iii) a Charpy notched impact strength measured according to ISO 179-1eA:2000 at 23°C in the range from 14.0 to 25.0 kJ/m², preferably 15.0 to 20.0 kJ/m², and/or
- 30 iv) Charpy notched impact strength measured according to ISO 179-1eA:2000 at -20°C in the range from 6.0 to 10.0 kJ/m², more preferably in the range from 6.2 to 9.0 kJ/m².

According to another embodiment of the present invention, the propylene polymer (M) is a
35 propylene homopolymer, preferably the propylene polymer (M) is bimodal or trimodal.

According to yet another embodiment of the present invention, the propylene polymer (M) comprises at least two propylene polymer fractions (M-A) and (M-B), preferably the at least two propylene polymer fractions (M-A) and (M-B) differ from each other by the melt flow rate MFR₂ (230 °C / 2.16 kg) measured according to ISO 1133 and/or the melt flow rate MFR₂ (230 °C / 2.16 kg) measured according to ISO 1133 of the propylene polymer fraction (M-B) is lower than the melt flow rate MFR₂ (230 °C / 2.16 kg) measured according to ISO 1133 of the propylene polymer fraction (M-A).

According to one embodiment of the present invention, the propylene polymer (M) comprises two propylene polymer fractions (M-A) and (M-B), wherein

- (a) the first propylene polymer fraction (M-A) has a melt flow rate MFR₂ (230 °C / 2.16 kg) measured according to ISO 1133 in the range from 80.0 to 120.0 g/10min, preferably in the range from 85.0 to 110.0 g/10min, more preferably in the range from 90.0 to 105.0 g/10min; and/or
- (b) the second propylene polymer fraction (M-B) has a lower melt flow rate MFR₂ (230 °C / 2.16 kg) measured according to ISO 1133 than the first propylene polymer fraction (M-A) so that the melt flow rate MFR₂ (230 °C / 2.16 kg) measured according to ISO 1133 of the propylene polymer (M) is in the range from 60.0 to 90.0 g/10min, preferably in the range from 65.0 to 85.0 g/10min, more preferably in the range from 70.0 to 80.0 g/10min.

According to another embodiment of the present invention, the propylene polymer (M) comprises three propylene polymer fractions (M-A), (M-B) and (M-C), wherein

- (a) the first propylene polymer fraction (M-A) has a melt flow rate MFR₂ (230 °C / 2.16 kg) measured according to ISO 1133 in the range from 200.0 to 250.0 g/10min, preferably in the range from 204.0 to 240.0 g/10min, more preferably in the range from > 204.0 to 235.0 g/10min; and/or
- (b) the second propylene polymer fraction (M-B) has a melt flow rate MFR₂ (230 °C / 2.16 kg) measured according to ISO 1133 being lower than the melt flow rate MFR₂ (230 °C / 2.16 kg) measured according to ISO 1133 of the first propylene polymer fraction (M-A) so that the mixture of (a) and (b) has a melt flow rate MFR₂ (230 °C / 2.16 kg) measured according to ISO 1133 in the range from 150.0 to 210.0 g/10min, preferably in the range from 155.0 to < 204.0 g/10min, more preferably in the range from 165.0 to < 204.0 g/10min, and/or

(c) the third propylene polymer fraction (M-C) has a melt flow rate MFR_2 (230 °C / 2.16 kg) measured according to ISO 1133 of the mixture of (a) and (b) so that the melt flow rate MFR_2 (230 °C / 2.16 kg) measured according to ISO 1133 of the propylene polymer (M) is in the range from 50.0 to 80.0 g/10min, preferably in the range from 60.0 to 70.0 g/10min, more preferably in the range from 62.0 to 68.0 g/10min.

According to yet another embodiment of the present invention, one of the propylene polymer fractions (M-A) and (M-B) and optional (M-C) is a propylene homopolymer, preferably each of the propylene polymer fractions (M-A), (M-B) and optional (M-C) is a propylene homopolymer, and/or each of the propylene polymer fractions (M-A), (M-B) and optional (M-C) has a xylene cold soluble (XCS) content in the range from 0 to 5 wt.-%.

According to one embodiment of the present invention, the elastomeric ethylene-propylene copolymer (E) has a comonomer content in the range from 33 to 39 wt.-%, preferably from 33.5 to 38.5 wt.-%, determined as the comonomer content of the xylene cold soluble (XCS) fraction of the heterophasic propylene copolymer (HECO).

According to another embodiment of the present invention, the elastomeric ethylene-propylene copolymer (E) comprises one or two elastomeric ethylene-propylene copolymer fractions (E-A) and optionally (E-B).

According to another aspect, the present invention relates to an article comprising the heterophasic propylene copolymer (HECO) composition as defined herein.

According to one embodiment of the present invention, the article is a molded article like an injection molded article or a compression molded article, such as parts of car seats, paint pails, strollers, baby walkers, toys, heavy duty pails or transport packagings.

According to a further aspect, the present invention relates to the use of the heterophasic propylene copolymer (HECO) composition as defined herein for the preparation of an article as defined herein.

In the following, the present invention is described in more detail.

The heterophasic propylene copolymer (HECO) composition

The heterophasic propylene copolymer (HECO) composition according to the present invention comprises

- 5 a) a matrix being a propylene polymer (M), which is optionally at least bimodal, and
- b) an elastomeric ethylene-propylene copolymer (E) being dispersed in said matrix, the elastomeric ethylene-propylene copolymer (E) has an intrinsic viscosity (IV) in the range from 3.3 to 5.0 dl/g and an ethylene content in the
- 10 range from 34 to 60 wt.% based on the total weight of the elastomeric ethylene-propylene copolymer (E),
- wherein the xylene cold soluble fraction (XCS) is in the range from 25.0 to 50.0 wt.-%, based on the total weight of the composition.

- 15 The heterophasic propylene copolymer (HECO) composition preferably comprises at least 80.0 wt.-% of a heterophasic propylene copolymer (HECO), said heterophasic propylene copolymer (HECO) comprising a matrix being a propylene polymer (M), and an elastomeric ethylene-propylene copolymer (E) being dispersed in said matrix, the elastomeric ethylene-propylene copolymer (E) having an intrinsic viscosity (IV) in the range from 3.3 to 5.0 dl/g
- 20 and an ethylene content in the range from 34 to 60 wt.% based on the total weight of the elastomeric ethylene-propylene copolymer (E). For example, the heterophasic propylene copolymer (HECO) composition comprises at least 84.0 wt.-% of a heterophasic propylene copolymer (HECO), said heterophasic propylene copolymer (HECO) comprising a matrix being a propylene polymer (M), and an elastomeric ethylene-propylene copolymer (E) being
- 25 dispersed in said matrix, the elastomeric ethylene-propylene copolymer (E) having an intrinsic viscosity (IV) in the range from 3.3 to 5.0 dl/g and an ethylene content in the range from 34 to 60 wt.% based on the total weight of the elastomeric ethylene-propylene copolymer (E). In one embodiment, the heterophasic propylene copolymer (HECO) composition comprises at least 86.0 wt.-% of a heterophasic propylene copolymer (HECO),
- 30 said heterophasic propylene copolymer (HECO) comprising a matrix being a propylene polymer (M), and an elastomeric ethylene-propylene copolymer (E) being dispersed in said matrix, the elastomeric ethylene-propylene copolymer (E) having an intrinsic viscosity (IV) in the range from 3.3 to 5.0 dl/g and an ethylene content in the range from 34 to 60 wt.% based on the total weight of the elastomeric ethylene-propylene copolymer (E).

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In one embodiment, the heterophasic propylene copolymer (HECO) composition comprises

at least 88.0 wt.-% of a heterophasic propylene copolymer (HECO), said heterophasic propylene copolymer (HECO) comprising a matrix being a propylene polymer (M), and an elastomeric ethylene-propylene copolymer (E) being dispersed in said matrix, the elastomeric ethylene-propylene copolymer (E) having an intrinsic viscosity (IV) in the range
5 from 3.3 to 5.0 dl/g and an ethylene content in the range from 34 to 60 wt.% based on the total weight of the elastomeric ethylene-propylene copolymer (E).

The heterophasic propylene copolymer (HECO) composition of the present invention may include additives (AD).
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Accordingly, it is preferred that the heterophasic propylene copolymer (HECO) composition comprises, more preferably consists of, 80.0 to 98.0 wt.-%, more preferably 84.0 to 96.0 wt.-%, still more preferably 86.0 to 94.0 wt.-%, like 88.0 to 92.0 wt.-% of the heterophasic propylene copolymer (HECO), and 2.0 to 20.0 wt.-%, more preferably 4.0 to 16.0 wt.-%, still
15 more preferably 6.0 to 14.0 wt.-%, like 8.0 to 12.0 wt.-% of additives (AD), based on the overall weight of the heterophasic propylene copolymer (HECO) composition. The additives (AD) are described in more detail below.

Preferably the heterophasic propylene copolymer (HECO) composition of the invention does not comprise (a) further polymer(s) different to the matrix being a propylene polymer (M) and the elastomeric ethylene-propylene copolymer (E) being dispersed in said matrix in an amount exceeding 15 wt.-%, preferably in an amount exceeding 10 wt.-%, more preferably in an amount exceeding 9 wt. %, based on the overall weight of the heterophasic propylene copolymer (HECO) composition.
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It is appreciated that the heterophasic propylene copolymer (HECO) is preferably the only polymer present in the heterophasic propylene copolymer (HECO) composition.
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In one embodiment, the heterophasic propylene copolymer (HECO) composition consists of the heterophasic propylene copolymer (HECO) comprising a matrix being a propylene polymer (M), and an elastomeric ethylene-propylene copolymer (E) being dispersed in said matrix, the elastomeric ethylene-propylene copolymer (E) having an intrinsic viscosity (IV) in the range from 3.3 to 5.0 dl/g and an ethylene content in the range from 34 to 60 wt.% based on the total weight of the elastomeric ethylene-propylene copolymer (E).
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It is preferred that the heterophasic propylene copolymer (HECO) composition has a moderate melt flow rate and thus provides a sufficient processability. Thus, it is preferred
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that the melt flow rate MFR₂ (230 °C, 2.16 kg) determined according to ISO 1133 of the heterophasic propylene copolymer (HECO) composition is in the range of 10.0 to 30.0 g/10 min, more preferably in the range of 12.0 to 18.0 g/10 min, still more preferably in the range of 13.0 to 18.0 g/10 min, like in the range of 14.0 to 17.0 g/10 min.

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As outlined above, it is preferred that the heterophasic propylene copolymer (HECO) composition according to the present invention is a rather stiff material. Accordingly, it is preferred that the heterophasic propylene copolymer (HECO) composition has a flexural modulus determined according to ISO 178 on injection molded specimen of 1000 to 1400 MPa, more preferably in the range of 1050 to 1250 MPa.

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Further, it is preferred that the heterophasic propylene copolymer (HECO) composition according to the present invention has excellent impact properties at room temperature as well as low temperature. Therefore, it is preferred that the heterophasic propylene copolymer (HECO) composition has a Charpy notched impact strength determined according to ISO 179 / 1eA:2000 at 23 °C in the range of 14.0 to 25.0 kJ/m², more preferably in the range of 15.0 to 20.0 kJ/m².

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Additionally or alternatively, it is preferred that the heterophasic propylene copolymer (HECO) composition has a Charpy notched impact strength determined according to ISO 179 / 1eA:2000 at -20 °C in the range of 6.0 to 10.0 kJ/m², more preferably in the range of 6.2 to 9.0 kJ/m².

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In view of this, the heterophasic propylene copolymer (HECO) composition preferably has

- i) a melt flow rate MFR₂ (230°C, 2.16 kg) determined according to ISO 1133 in the range of 10 to 30 g/10min, preferably 12 to 18 g/10 min, and/or
- ii) a flexural modulus measured according to ISO 178 on injection molded specimen of 1000 to 1400 MPa, preferably from 1050 to 1250 MPa, and/or
- iii) a Charpy notched impact strength measured according to ISO 179-1eA:2000 at 23°C in the range from 14.0 to 25.0 kJ/m², preferably 15.0 to 20.0 kJ/m², and/or
- iv) Charpy notched impact strength measured according to ISO 179-1eA:2000 at -20°C in the range from 6.0 to 10.0 kJ/m², more preferably in the range from 6.2 to 9.0 kJ/m².

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For example, the heterophasic propylene copolymer (HECO) composition preferably has

- i) a melt flow rate MFR_2 (230°C, 2.16 kg) determined according to ISO 1133 in the range of 10 to 30 g/10min, preferably 12 to 18 g/10 min, or
- ii) a flexural modulus measured according to ISO 178 on injection molded specimen of 1000 to 1400 MPa, preferably from 1050 to 1250 MPa, or
- 5 iii) a Charpy notched impact strength measured according to ISO 179-1eA:2000 at 23°C in the range from 14.0 to 25.0 kJ/m², preferably 15 to 20 kJ/m², or
- iv) Charpy notched impact strength measured according to ISO 179-1eA:2000 at -20°C in the range from 6.0 to 10.0 kJ/m², more preferably in the range
- 10 from 6.2 to 9.0 kJ/m².

Preferably, the heterophasic propylene copolymer (HECO) composition preferably has

- i) a melt flow rate MFR_2 (230°C, 2.16 kg) determined according to ISO 1133 in the range of 10 to 30 g/10min, preferably 12 to 18 g/10 min, and
- 15 ii) a flexural modulus measured according to ISO 178 on injection molded specimen of 1000 to 1400 MPa, preferably from 1050 to 1250 MPa, and
- iii) a Charpy notched impact strength measured according to ISO 179-1eA:2000 at 23°C in the range from 14.0 to 25.0 kJ/m², preferably 15 to 20 kJ/m², and
- 20 iv) Charpy notched impact strength measured according to ISO 179-1eA:2000 at -20°C in the range from 6.0 to 10.0 kJ/m², more preferably in the range from 6.2 to 9.0 kJ/m².

25 Preferably, it is desired that the heterophasic propylene copolymer (HECO) composition is thermo mechanically stable. Accordingly, it is appreciated that the heterophasic propylene copolymer (HECO) composition has a melting temperature of at least 160 °C, more preferably in the range of 162 to 170 °C, still more preferably in the range of 163 to 168 °C.

30 The heterophasic propylene copolymer (HECO) composition according to the present invention comprises a matrix being propylene polymer (M) and dispersed therein an elastomeric ethylene-propylene copolymer (E). Thus, the matrix contains (finely) dispersed inclusions being not part of the matrix (M) and said inclusions contain the elastomeric ethylene-propylene copolymer. The term inclusion indicates that the matrix (M) and the inclusion form different phases within the heterophasic propylene copolymer (HECO)

35 composition. The presence of second phases or the so called inclusions are for instance visible by high resolution microscopy, like electron microscopy or atomic force microscopy,

or by dynamic mechanical thermal analysis (DMTA). Specifically, in DMTA the presence of a multiphase structure can be identified by the presence of at least two distinct glass transition temperatures.

- 5 Accordingly, the heterophasic propylene copolymer (HECO) composition according to this invention preferably comprises
- (a) the propylene polymer as the matrix (M), and
 - (b) the elastomeric ethylene-propylene copolymer (E) as the dispersed phase.
- 10 It is preferred that the overall amount of the elastomeric ethylene-propylene copolymer (E) within the heterophasic propylene copolymer (HECO) composition is rather high. Therefore, it is preferred that the weight ratio between the propylene polymer (M) and the elastomeric ethylene-propylene copolymer (E) [M/E] of the heterophasic propylene copolymer (HECO) is in the range of 75/25 to 70/30, more preferably in the range of 74/26 to 71/29, yet more
- 15 preferably in the range of 74/26 to 72/28.

- Preferably, heterophasic propylene copolymer (HECO) composition according to this invention comprises as polymer components only the propylene polymer (M) and the elastomeric ethylene-propylene copolymer (E). In other words, the heterophasic propylene
- 20 copolymer (HECO) composition may contain further additives but no other polymer in an amount exceeding 5.0 wt.-%, more preferably exceeding 3.0 wt.-%, like exceeding 1.0 wt.-%, based on the total heterophasic propylene copolymer (HECO) composition. One additional polymer which may be present in such low amounts is a polyethylene which is a reaction-by-product obtained by the preparation of the heterophasic propylene copolymer (HECO)
- 25 composition. Accordingly, it is in particular appreciated that the heterophasic propylene copolymer (HECO) composition contains only the propylene polymer (M), the elastomeric ethylene-propylene copolymer (E) and optionally polyethylene in amounts as mentioned in this paragraph.
- 30 The heterophasic propylene copolymer (HECO) composition comprises apart from propylene also comonomers. Preferably, the heterophasic propylene copolymer (HECO) composition comprises apart from propylene ethylene and optionally C₄ to C₈ α -olefins. Accordingly, the term "propylene copolymer" according to this invention is understood as a polypropylene comprising, preferably consisting of, units derivable from
- 35 (a) propylene
- and

(b) ethylene and optionally C₄ to C₈ α -olefins.

Thus, the heterophasic propylene copolymer (HECO) composition, i.e. the propylene polymer (M) as well as the elastomeric ethylene-propylene copolymer (E), can comprise
5 monomers copolymerizable with propylene, especially ethylene and optionally C₄ to C₈ α -olefins, in particular C₄ to C₈ α -olefins, e.g. 1-butene and/or 1-hexene. Preferably, the heterophasic propylene copolymer (HECO) composition according to this invention comprises, especially consists of, monomers copolymerizable with propylene selected from ethylene and optionally 1-butene and 1-hexene. More specifically, the heterophasic
10 propylene copolymer (HECO) composition of this invention comprises - apart from propylene - units derivable from ethylene and optionally 1-butene. In a preferred embodiment, the heterophasic propylene copolymer (HECO) composition according to this invention comprises units derivable from ethylene and propylene only. Still more preferably the propylene polymer (M) as well as the elastomeric ethylene-propylene copolymer (E) of the
15 heterophasic propylene copolymer (HECO) composition contain the same comonomers, like ethylene.

Additionally, it is appreciated that the heterophasic propylene copolymer (HECO) composition preferably has a moderate total comonomer content, preferably ethylene
20 content. Thus, it is preferred that the comonomer content of the heterophasic propylene copolymer (HECO) composition is in the range of 9.0 to 12.5 wt.-%, preferably in the range of 9.2 to 12.5 wt.-%, more preferably in the range of 9.4 to 12.3 wt.-%, like in the range of 9.6 to 12.3 wt.-%. It may be further preferred that the comonomer content of the heterophasic propylene copolymer (HECO) composition may be for example in the range of 9.6 to 12.3
25 wt.-%, preferably in the range of 9.8 to 12.3 mol.-%, preferably in the range of 10.0 to 12.3 wt.-%, preferably in the range of 10.2 to 12.3 wt.-%, further preferred in the range of 10.4 to 12.3 wt.-%, more preferably in the range of 10.6 to 12.3 mol.-%, like in the range of 10.8 to 12.3 wt.-%.

30 One requirement of the present invention is that the heterophasic propylene copolymer (HECO) composition contains a high amount of a xylene cold soluble (XCS) fraction. Thus, it is appreciated that the xylene cold soluble (XCS) fraction measured according to according ISO 16152 (25 °C) of the heterophasic propylene copolymer (HECO) composition is in the range of 25.0 to 50.0 wt.-%, more preferably in the range of 25.5 to 40.0 wt.-%, still more
35 preferably in the range of 25.5 to 35.0 wt.-%, like in the range of 25.5 to 30.0 wt.-%, based on the overall weight of the heterophasic propylene copolymer (HECO) composition.

Further, it is appreciated that the xylene cold soluble (XCS) fraction of the heterophasic propylene copolymer (HECO) is specified by its intrinsic viscosity. For the present invention it is preferred that the xylene cold soluble fraction (XCS) of the heterophasic propylene
5 copolymer (HECO) has an intrinsic viscosity (IV) measured according to ISO 1628/1 (at 135 °C in decalin) in the range of 3.3 to 5.0 dl/g.

Additionally, it is preferred that the comonomer content, i.e. ethylene content, of the xylene cold soluble (XCS) fraction of the heterophasic propylene copolymer (HECO) is in the range
10 of 34 to 60 wt.-%, more preferably in the range of 33 to 39 wt.-%. The comonomers present in the xylene cold soluble (XCS) fraction are those defined above for the propylene polymer (M) and the elastomeric ethylene-propylene copolymer (E), respectively. In one preferred embodiment, the comonomer is ethylene only.

15 The heterophasic propylene copolymer (HECO) can be further defined by its individual components, i.e. the propylene polymer (M) and the elastomeric ethylene-propylene copolymer (E).

20 The propylene polymer (M) can be a propylene copolymer or a propylene homopolymer, the latter being preferred.

In case the propylene polymer (M) is a propylene copolymer, the propylene polymer (M) comprises monomers copolymerizable with propylene, for example comonomers such as ethylene and/or C₄ to C₈ α-olefins, in particular ethylene and/or C₄ to C₈ α-olefins, e.g. 1-
25 butene and/or 1-hexene. Preferably, the propylene polymer (M) according to this invention comprises, especially consists of, monomers copolymerizable with propylene from the group consisting of ethylene, 1-butene and 1-hexene. More specifically, the propylene polymer (M) of this invention comprises - apart from propylene - units derivable from ethylene and/or 1-butene. In a preferred embodiment the propylene polymer (M) comprises units derivable
30 from ethylene and propylene only.

The propylene polymer (M) according to this invention preferably has a melt flow rate MFR₂ (230 °C/2.16 kg) measured according to ISO 1133 in the range of 50.0 to 90.0 g/10 min, more preferably in the range of 60.0 to 85.0 g/10 min, still more preferably in the range of
35 62.0 to 80.0 g/10 min.

The comonomer content of the propylene polymer (M) is in the range of 0.0 to 5.0 wt.-%, yet more preferably in the range of 0.0 to 3.0 wt.-%, still more preferably in the range of 0.0 to 1.0 wt.-%.

5 It is especially preferred that the propylene polymer (M) is a propylene homopolymer. It is thus appreciated that the comonomer content of the propylene polymer (M) is in the range of 0.0 to 0.5 wt.-%, yet more preferably in the range of 0.0 to 0.2 wt.-%. Most preferably, the propylene polymer (M) consists of propylene units, i.e. is free of comonomer units, like ethylene units.

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Further, it is preferred that the propylene polymer (M) is multimodal. That is to say, the propylene polymer (M) is at least bimodal, e.g. bimodal or trimodal. Thus, the propylene polymer (M) comprises, preferably consists of, a first propylene polymer fraction (M-A), a second propylene polymer fraction (M-B) and optionally a third propylene polymer fraction (M-C).

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It is preferred that one of the propylene polymer fractions (M-A) and (M-B) and optional (M-C) is a propylene homopolymer. In case the propylene polymer (M) is a propylene homopolymer also its fractions are propylene homopolymer fractions, i.e. each of the propylene polymer fractions (M-A), (M-B) and optional (M-C) is a propylene homopolymer.

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Additionally or alternatively, it is preferred that each of the propylene polymer fractions (M-A), (M-B) and optional (M-C) has a xylene cold soluble (XCS) content in the range from 0 to 5 wt.-%.

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Accordingly, the propylene polymer (M) preferably comprises at least two propylene polymer fractions, like two or three polymer fractions, all of them are preferably propylene homopolymers. Even more preferably, the propylene polymer (M) comprises, preferably consists of, a first propylene polymer fraction (M-A) and a second propylene polymer fraction (M-B), like a first propylene homopolymer fraction (M-A) and a second propylene homopolymer fraction (M-B). Alternatively, the propylene polymer (M) comprises, preferably consists of, a first propylene polymer fraction (M-A), a second propylene polymer fraction (M-B) and a third propylene polymer fraction (M-C), like a first propylene homopolymer fraction (M-A), a second propylene homopolymer fraction (M-B) and a third propylene homopolymer fraction (M-C).

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In case, the propylene polymer (M) comprises, preferably consists of, a first propylene polymer fraction (M-A) and a second propylene polymer fraction (M-B), like a first propylene homopolymer fraction (M-A) and a second propylene homopolymer fraction (M-B), the first propylene polymer fraction (M-A) and the second propylene polymer fraction (M-B)
5 preferably differ from each other by the melt flow rate MFR_2 (230 °C / 2.16 kg) measured according to ISO 1133.

Accordingly, the propylene polymer (M) comprises two propylene polymer fractions (M-A) and (M-B), wherein
10 (a) the first propylene polymer fraction (M-A) has a melt flow rate MFR_2 (230 °C / 2.16 kg) measured according to ISO 1133 in the range from 80.0 to 120.0 g/10min, preferably in the range from 85.0 to 110.0 g/10min, more preferably in the range from 90.0 to 105.0 g/10min; and/or
(b) the second propylene polymer fraction (M-B) has a lower melt flow rate
15 MFR_2 (230 °C / 2.16 kg) measured according to ISO 1133 than the first propylene polymer fraction (M-A) so that the melt flow rate MFR_2 (230 °C / 2.16 kg) measured according to ISO 1133 of the propylene polymer (M) is in the range from 60.0 to 90.0 g/10min, preferably in the range from 65.0 to 85.0 g/10min, more preferably in the range from 70.0 to 80.0 g/10min.
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Preferably, the propylene polymer (M) comprises two propylene polymer fractions (M-A) and (M-B), wherein
(a) the first propylene polymer fraction (M-A) has a melt flow rate MFR_2 (230 °C / 2.16 kg) measured according to ISO 1133 in the range from 80.0 to 120.0 g/10min, preferably in the range from 85.0 to 110.0 g/10min, more preferably in the range from 90.0 to 105.0 g/10min; and
25 (b) the second propylene polymer fraction (M-B) has a lower melt flow rate MFR_2 (230 °C / 2.16 kg) measured according to ISO 1133 than the first propylene polymer fraction (M-A) so that the melt flow rate MFR_2 (230 °C / 2.16 kg) measured according to ISO 1133 of the propylene polymer (M) is in the range from 60.0 to 90.0 g/10min, preferably in the range from 65.0 to 85.0 g/10min, more preferably in the range from 70.0 to 80.0 g/10min.
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It is preferred that the melt flow rate MFR_2 (230 °C / 2.16 kg) measured according to ISO 1133 of the propylene polymer fraction (M-B) is lower than the melt flow rate MFR_2 (230 °C / 2.16 kg) measured according to ISO 1133 of the propylene polymer fraction (M-A).

- 5 In one embodiment, the propylene polymer (M) comprises, preferably consists of, a first propylene polymer fraction (M-A), a second propylene polymer fraction (M-B) and a third propylene polymer fraction (M-C), like a first propylene homopolymer fraction (M-A), a second propylene homopolymer fraction (M-B) and a third propylene polymer fraction (M-C). It is appreciated that the first propylene polymer fraction (M-A), the second propylene
10 polymer fraction (M-B) and the third propylene polymer fraction (M-C), like the first propylene homopolymer fraction (M-A), the second propylene homopolymer fraction (M-B) and the third propylene polymer fraction (M-C) differ from each other by the melt flow rate MFR_2 (230 °C / 2.16 kg) measured according to ISO 1133. In this case, the first propylene polymer fraction (M-A) and the second propylene polymer fraction (M-B) preferably have a similar melt flow
15 rate MFR_2 (230 °C / 2.16 kg) measured according to ISO 1133. That is to say, the melt flow rate MFR_2 (230 °C / 2.16 kg) measured according to ISO 1133 of the first propylene polymer fraction (M-A) and the second propylene polymer fraction (M-B) preferably do not differ more than 10 g/10min, more preferably not more than 5 g/10min, still more preferably not more than 2 g/10min.

20 However, it is preferred that the melt flow rate MFR_2 (230 °C / 2.16 kg) measured according to ISO 1133 of the third propylene polymer fraction (M-C) differs from the MFR_2 (230 °C / 2.16 kg) measured according to ISO 1133 of the first propylene polymer fraction (M-A) and the second propylene polymer fraction (M-B).

25 Thus, the propylene polymer (M) preferably comprises three propylene polymer fractions (M-A), (M-B) and (M-C), wherein

- (a) the first propylene polymer fraction (M-A) has a melt flow rate MFR_2 (230 °C / 2.16 kg) measured according to ISO 1133 in the range from 200.0 to 250.0
30 g/10min, preferably in the range from 204.0 to 240.0 g/10min, more preferably in the range from > 204.0 to 235.0 g/10min; and/or
- (b) the second propylene polymer fraction (M-B) has a melt flow rate MFR_2 (230 °C / 2.16 kg) measured according to ISO 1133 being lower than the melt flow rate MFR_2 (230 °C / 2.16 kg) measured according to ISO 1133 of the first propylene
35 polymer fraction (M-A) so that the mixture of (a) and (b) has a melt flow rate MFR_2 (230 °C / 2.16 kg) measured according to ISO 1133 in the range from 150.0 to 210.0

g/10min, preferably in the range from 155.0 to < 204.0 g/10min, more preferably in the range from 165.0 to < 204.0 g/10min, and/or

- (c) the third propylene polymer fraction (M-C) has a melt flow rate MFR_2 (230 °C / 2.16 kg) measured according to ISO 1133 of the mixture of (a) and (b) so that the melt flow rate MFR_2 (230 °C / 2.16 kg) measured according to ISO 1133 of the propylene polymer (M) is in the range from 50.0 to 80.0 g/10min, preferably in the range from 60.0 to 70.0 g/10min, more preferably in the range from 62.0 to 68.0 g/10min.

- 10 Preferably, the propylene polymer (M) comprises three propylene polymer fractions (M-A), (M-B) and (M-C), wherein

- (a) the first propylene polymer fraction (M-A) has a melt flow rate MFR_2 (230 °C / 2.16 kg) measured according to ISO 1133 in the range from 200.0 to 250.0 g/10min, preferably in the range from 204.0 to 240.0 g/10min, more preferably in the range from > 204.0 to 235.0 g/10min; and

- (b) the second propylene polymer fraction (M-B) has a melt flow rate MFR_2 (230 °C / 2.16 kg) measured according to ISO 1133 being lower than the melt flow rate MFR_2 (230 °C / 2.16 kg) measured according to ISO 1133 of the first propylene polymer fraction (M-A) so that the mixture of (a) and (b) has a melt flow rate MFR_2 (230 °C / 2.16 kg) measured according to ISO 1133 in the range from 150.0 to 210.0 g/10min, preferably in the range from 155.0 to < 204.0 g/10min, more preferably in the range from 165.0 to < 204.0 g/10min, and

- (c) the third propylene polymer fraction (M-C) has a melt flow rate MFR_2 (230 °C / 2.16 kg) measured according to ISO 1133 of the mixture of (a) and (b) so that the melt flow rate MFR_2 (230 °C / 2.16 kg) measured according to ISO 1133 of the propylene polymer (M) is in the range from 50.0 to 80.0 g/10min, preferably in the range from 60.0 to 70.0 g/10min, more preferably in the range from 62.0 to 68.0 g/10min.

- 30 It is preferred that each of the first propylene polymer fraction (M-A) and the second propylene polymer fraction (M-B) has a higher melt flow rate MFR_2 than the third propylene polymer fraction (M-C).

- Accordingly, the first propylene polymer fraction (M-A) and the second propylene polymer fraction (M-B) are the high melt flow rate MFR_2 (230 °C / 2.16 kg) fraction and the third propylene polymer fraction (M-C) is the low melt flow rate MFR_2 (230 °C / 2.16 kg) fraction.

The heterophasic propylene copolymer (HECO) composition preferably comprises from 50.0 to 75.0 wt.-%, more preferably from 55.0 to 74.5 wt.-%, still more preferably from 60.0 to 74.5 wt.-%, like from 65.0 to 74.5 wt.-%, of the propylene polymer (M), based on the total weight of the heterophasic propylene copolymer (HECO) composition.

Additionally, the heterophasic propylene copolymer (HECO) composition preferably comprises from 25.0 to 50.0 wt.-%, more preferably from 25.5 to 45.0 wt.-%, still more preferably from 25.5 to 40.0 wt.-%, like from 35.0 to 28.5 wt.-%, of the elastomeric ethylene-propylene copolymer (E), based on the total weight of the heterophasic propylene copolymer (HECO) composition.

Thus, it is appreciated that the heterophasic propylene copolymer (HECO) composition preferably comprises, more preferably consists of, 50.0 to 75.0 wt.-%, more preferably from 55.0 to 74.5 wt.-%, still more preferably from 60.0 to 74.5 wt.-%, like from 65.0 to 74.5 wt.-%, of the propylene polymer (M), and 25.0 to 50.0 wt.-%, more preferably from 25.5 to 45.0 wt.-%, still more preferably from 25.5 to 40.0 wt.-%, like from 35.0 to 28.5 wt.-%, of the elastomeric ethylene-propylene copolymer (E), based on the total weight of the heterophasic propylene copolymer (HECO) composition.

Accordingly, a further component of the heterophasic propylene copolymer (HECO) composition is the elastomeric ethylene-propylene copolymer (E) dispersed in the matrix (M) being the propylene polymer (M). Concerning the comonomers used in the elastomeric ethylene-propylene copolymer (E), it is referred to the information provided for the heterophasic propylene copolymer (HECO) composition. Accordingly, the elastomeric ethylene-propylene copolymer (E) comprises monomers copolymerizable with propylene, especially ethylene and optionally C₄ to C₈ α-olefins, in particular C₄ to C₆ α-olefins, e.g. 1-butene and/or 1-hexene. Preferably, the elastomeric ethylene-propylene copolymer (E) comprises, especially consists of, monomers copolymerizable with propylene selected from ethylene and optionally 1-butene and 1-hexene. More specifically, the elastomeric ethylene-propylene copolymer (E) comprises - apart from propylene - units derivable from ethylene and optionally 1-butene. Thus, in an especially preferred embodiment the elastomeric ethylene-propylene copolymer (E) comprises units derivable from ethylene and propylene only.

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The comonomer content, preferably ethylene content, of the elastomeric ethylene-propylene copolymer (E) preferably is in the range from 34.0 to 60.0 wt.-%, more preferably in the range from 33.0 to 39.0 wt.-%, and most preferably from 33.5 to 38.5 wt.-%, determined as the comonomer content of the xylene cold soluble (XCS) fraction of the heterophasic propylene copolymer (HECO) composition.

Further, it is preferred that the elastomeric ethylene-propylene copolymer (E) is unimodal or multimodal, like bimodal. Thus, the elastomeric ethylene-propylene copolymer (E) preferably comprises, more preferably consists of, one or two elastomeric ethylene-propylene copolymer fractions (E-A) and optionally (E-B).

It is preferred that each of the elastomeric ethylene-propylene copolymer fractions (E-A) and optionally (E-B) is a propylene copolymer.

Additionally or alternatively, it is preferred that each of the propylene polymer fractions (M-A), (M-B) and optional (M-C) has a xylene cold soluble (XCS) content in the range from 20.0 to 30.0 wt.-%.

It is appreciated that the elastomeric ethylene-propylene copolymer (E) is preferably unimodal, i.e. comprises, preferably consists of, a first elastomeric ethylene-propylene copolymer fraction (E-A), if the propylene polymer (M) is trimodal, i.e. comprises, preferably consists of, a first propylene polymer fraction (M-A), a second propylene polymer fraction (M-B) and a third propylene polymer fraction (M-C), like a first propylene homopolymer fraction (M-A), a second propylene homopolymer fraction (M-B) and a third propylene homopolymer fraction (M-C).

Alternatively, the elastomeric ethylene-propylene copolymer (E) is bimodal, i.e. comprises, preferably consists of, a first elastomeric ethylene-propylene copolymer fraction (E-A) and a second elastomeric ethylene-propylene copolymer fraction (E-B), if the propylene polymer (M) is bimodal, i.e. comprises, preferably consists of, a first propylene polymer fraction (M-A) and a second propylene polymer fraction (M-B), like a first propylene homopolymer fraction (M-A) and a second propylene homopolymer fraction (M-B).

In case, the elastomeric ethylene-propylene copolymer (E) is bimodal, i.e. comprises, preferably consists of, a first elastomeric ethylene-propylene copolymer fraction (E-A) and a second elastomeric ethylene-propylene copolymer fraction (E-B), the first elastomeric

ethylene-propylene copolymer fraction (E-A) and the second elastomeric ethylene-propylene copolymer fraction (E-B) preferably differ from each other by the comonomer content.

5 It is preferred that the first elastomeric ethylene-propylene copolymer fraction (E-A) has a lower comonomer content than the second elastomeric ethylene-propylene copolymer fraction (E-B).

10 It is appreciated that the heterophasic propylene copolymer (HECO) composition may comprise additives. For example, the heterophasic propylene copolymer (HECO) composition comprises a first α -nucleating agent (NU1). Accordingly, it is preferred that the heterophasic propylene copolymer (HECO) is free of β -nucleating agents. The first α -nucleating agent (NU1) is preferably selected from the group consisting of

- (i) salts of monocarboxylic acids and polycarboxylic acids, e.g. sodium benzoate or aluminum tert-butylbenzoate, and
- 15 (ii) dibenzylidenesorbitol (e.g. 1,3 : 2,4 dibenzylidenesorbitol) and C₁-C₈-alkyl-substituted dibenzylidenesorbitol derivatives, such as methyldibenzylidenesorbitol, ethyldibenzylidenesorbitol or dimethyldibenzylidenesorbitol (e.g. 1,3 : 2,4 di(methylbenzylidene) sorbitol), or substituted nonitol-derivatives, such as 1,2,3,-trideoxy-4,6:5,7-bis-O-[(4-propylphenyl)methylene]-nonitol, and
- 20 (iii) salts of diesters of phosphoric acid, e.g. sodium 2,2'-methylenebis (4, 6,-di-tert-butylphenyl) phosphate or aluminum-hydroxy-bis[2,2'-methylene-bis(4,6-di-tert-butylphenyl)phosphate], and
- (iv) vinylcycloalkane polymer and vinylalkane polymer (as discussed in more detail below), and
- 25 (v) mixtures thereof.

Preferably the heterophasic propylene copolymer (HECO) composition, contains up to 5.0 wt.-% of the first α -nucleating agent (NU1). In a preferred embodiment, the heterophasic propylene copolymer (HECO) composition contains not more than 500 ppm, more preferably

30 of 0.025 to 200 ppm, more preferably of 0.1 to 200 ppm, still more preferably 0.3 to 200 ppm, most preferably 0.3 to 100 ppm of the first α -nucleating agent (NU1), in particular selected from the group consisting of dibenzylidenesorbitol (e.g. 1,3 : 2,4 dibenzylidene sorbitol), dibenzylidenesorbitol derivative, preferably dimethyldibenzylidenesorbitol (e.g. 1,3 : 2,4 di(methylbenzylidene) sorbitol), or substituted nonitol-derivatives, such as 1,2,3,-trideoxy-

35 4,6:5,7-bis-O-[(4-propylphenyl)methylene]-nonitol, sodium 2,2'-methylenebis (4, 6,-di-tert-

butylphenyl) phosphate, vinylcycloalkane polymer, vinylalkane polymer, and mixtures thereof.

5 It is particularly preferred that the first α -nucleating agent (NU1) is a polymeric α -nucleating agent.

Accordingly, it is preferred that the first α -nucleating agent (NU1) is vinylcycloalkane polymer and/or a vinylalkane polymer. It is especially preferred that the first α -nucleating agent (NU1) is vinylcycloalkane polymer as described in more detail below.

10 The heterophasic propylene copolymer (HECO) composition may further comprises a second α -nucleating agent (NU2) which is different from the first α -nucleating agent (NU1) of the heterophasic propylene copolymer (HECO) composition.

15 If present, the second α -nucleating agent (NU2) is preferably a non-polymeric nucleating agent.

The second α -nucleating agent (NU2) is preferably selected from the group consisting of

- 20 (i) salts of monocarboxylic acids and polycarboxylic acids, e.g. sodium benzoate or aluminum tert-butylbenzoate, and
- (ii) dibenzylidenesorbitol (e.g. 1,3 : 2,4 dibenzylidenesorbitol) and C₁-C₈-alkyl-substituted dibenzylidenesorbitol derivatives, such as methyl dibenzylidenesorbitol, ethyl dibenzylidenesorbitol or dimethyl dibenzylidenesorbitol (e.g. 1,3 : 2,4 di(methylbenzylidene) sorbitol), or substituted nonitol-derivatives, such as 1,2,3,-trideoxy-4,6:5,7-bis-O-[(4-propylphenyl)methylene]-nonitol, and
- 25 (iii) salts of diesters of phosphoric acid, e.g. sodium 2,2'-methylenebis (4, 6,-di-tert-butylphenyl) phosphate or aluminum-hydroxy-bis[2,2'-methylene-bis(4,6-di-tert-butylphenyl)phosphate],
- (iv) talc, and
- 30 (v) mixtures thereof.

It is especially preferred that the second α -nucleating agent (NU2) is talc.

The heterophasic propylene copolymer (HECO) composition comprises at least 1.4 wt.-%, preferably 1.4 to 5.0 wt.-%, more preferably 1.6 to 4.0 wt.-%, still more preferably 1.8 to 3.0 wt.-%, like 1.9 to 2.2 wt.-% of the second α -nucleating agent (NU2), if present.

Further, the heterophasic propylene copolymer (HECO) composition as defined in the instant invention may contain up to 5.0 wt.-% of further typical additives, like acid scavengers, antioxidants, colorants, light stabilisers, plasticizers, slip agents, anti-scratch agents,
5 dispersing agents, processing aids, lubricants, pigments, and the like. Preferably the content of such additives (without α -nucleating agents) is below 3.0 wt.-%, like below 1.0 wt.-%.

It is appreciated that the nucleating agents are regarded as additives (AD).

10 Additives as described herein are commercially available and for example described in "Plastic Additives Handbook", 6th edition 2009 of Hans Zweifel (pages 1141 to 1190).

Furthermore, the term "additives (AD)" according to the present invention also includes carrier materials, in particular polymeric carrier materials.

15 As mentioned above, the heterophasic propylene copolymer (HECO) composition of the invention does not comprise (a) further polymer(s) different to the propylene polymer (M) and the elastomeric ethylene-propylene copolymer (E) in an amount exceeding 15 wt.-%, preferably in an amount exceeding 10 wt.-%, more preferably in an amount exceeding 9 wt.-%,
20 %, based on the weight of the heterophasic propylene copolymer (HECO) composition. If an additional polymer is present, such a polymer is typically a polymeric carrier material for the additives (AD). Any carrier material for additives (AD) is not calculated to the amount of polymeric compounds as indicated in the present invention, but to the amount of the respective additive.

25 The polymeric carrier material of the additives (AD) is a carrier polymer to ensure a uniform distribution in the polypropylene composition (C) of the invention. The polymeric carrier material is not limited to a particular polymer. The polymeric carrier material may be ethylene homopolymer, ethylene copolymer obtained from ethylene and α -olefin comonomer such as
30 C₃ to C₈ α -olefin comonomer, propylene homopolymer and/or propylene copolymer obtained from propylene and α -olefin comonomer such as ethylene and/or C₄ to C₈ α -olefin comonomer.

The heterophasic propylene copolymer (HECO) composition can be produced by blending
35 the propylene polymer (M), the elastomeric ethylene-propylene copolymer (E) and the optional additives. However, it is preferred that the heterophasic propylene copolymer

(HECO) composition is produced in a sequential step process, using reactors in serial configuration and operating at different reaction conditions. As a consequence, each fraction prepared in a specific reactor may have its own molecular weight distribution and/or comonomer content distribution.

5

The heterophasic propylene copolymer (HECO) composition according to this invention is preferably produced in a sequential polymerization process, i.e. in a multistage process, known in the art, wherein the propylene polymer (M) is produced at least in one slurry reactor, preferably in a slurry reactor and in one or two subsequent gas phase reactor(s), and subsequently the elastomeric ethylene-propylene copolymer (E) is produced at least in one, i.e. one or two, gas phase reactor(s).

Accordingly it is preferred that the heterophasic propylene copolymer (HECO) composition is produced in a sequential polymerization process comprising the steps of

- 15 (a) polymerizing propylene in a first reactor (R1) obtaining the first propylene polymer fraction (M-A),
- (b) transferring the first propylene polymer fraction (M-A) into a second reactor (R2),
- (c) polymerizing in the second reactor (R2) and in the presence of said first propylene polymer fraction (M-A) propylene, thereby obtaining the second propylene polymer fraction (M-B),
- 20 (d) transferring the first propylene polymer fraction (M-A) and the second propylene polymer fraction (M-B) of step (c) into a third reactor (R3),
- (e) polymerizing in the third reactor (R3) and in the presence of the first propylene polymer fraction (M-A) and the second propylene polymer fraction (M-B) obtained in step (c) propylene and ethylene to obtain the first elastomeric ethylene-propylene copolymer fraction (E-A),
- 25 (f) transferring the first propylene polymer fraction (M-A), the second propylene polymer fraction (M-B) and the first elastomeric ethylene-propylene copolymer fraction (E-A) of step (e) into a fourth reactor (R4), and
- 30 (g) polymerizing in the fourth reactor (R4) and in the presence of the first propylene polymer fraction (M-A), the second propylene polymer fraction (M-B) and the first elastomeric ethylene-propylene copolymer fraction (E-A) obtained in step (e) propylene and ethylene to obtain the second elastomeric ethylene-propylene copolymer fraction (E-B), the first propylene polymer fraction (M-A), the second propylene polymer fraction (M-B), the first elastomeric ethylene-propylene copolymer
- 35

fraction (E-A) and the second elastomeric ethylene-propylene copolymer fraction (E-B) form the heterophasic propylene copolymer (HECO) composition.

- Alternatively, it is preferred that the heterophasic propylene copolymer (HECO) composition
- 5 is produced in a sequential polymerization process comprising the steps of
- (a) polymerizing propylene in a first reactor (R1) obtaining the first propylene polymer fraction (M-A),
 - (b) transferring the first propylene polymer fraction (M-A) into a second reactor (R2),
 - (c) polymerizing in the second reactor (R2) and in the presence of said first propylene
 - 10 polymer fraction (M-A) propylene, thereby obtaining the second propylene polymer fraction (M-B),
 - (d) transferring the first propylene polymer fraction (M-A) and the second propylene polymer fraction (M-B) of step (c) into a third reactor (R3),
 - (e) polymerizing in the third reactor (R3) and in the presence of the first propylene
 - 15 polymer fraction (M-A) and the second propylene polymer fraction (M-B) obtained in step (c) propylene to obtain the third propylene polymer fraction (M-C),
 - (f) transferring the first propylene polymer fraction (M-A), the second propylene polymer fraction (M-B) and the third propylene polymer fraction (M-C) of step (e) into a fourth reactor (R4), and
 - 20 (g) polymerizing in the fourth reactor (R4) and in the presence of the first propylene polymer fraction (M-A), the second propylene polymer fraction (M-B) and the third propylene polymer fraction (M-C) obtained in step (e) propylene and ethylene to obtain the first elastomeric ethylene-propylene copolymer fraction (E-A), the first propylene polymer fraction (M-A), the second propylene polymer fraction (M-B), the
 - 25 third propylene polymer fraction (M-C) and the first elastomeric ethylene-propylene copolymer fraction (E-A) form the heterophasic propylene copolymer (HECO) composition.

Of course, in the first reactor (R1) the second and optionally third propylene polymer

30 fraction(s) (M-B, M-C) can be produced and in the second reactor (R2) the first propylene polymer fraction (M-A) can be obtained.

The term "sequential polymerization process" indicates that the heterophasic propylene copolymer (HECO) composition is produced in at least two, like three or four reactors

35 connected in series. Accordingly, the present process comprises at least a first reactor (R1) and a second reactor (R2), more preferably a first reactor (R1), a second reactor (R2), a third

reactor (R3) and a fourth reactor (R4). The term "polymerization reactor" shall indicate that the main polymerization takes place. Thus in case the process consists of four polymerization reactors, this definition does not exclude the option that the overall process comprises for instance a pre-polymerization step in a pre-polymerization reactor. The term
5 "consist of" is only a closing formulation in view of the main polymerization reactors.

The first reactor (R1) is preferably a slurry reactor (SR) and can be any continuous or simple stirred batch tank reactor or loop reactor operating in bulk or slurry. Bulk means a polymerization in a reaction medium that comprises of at least 60 % (w/w) monomer.
10 According to the present invention the slurry reactor (SR) is preferably a (bulk) loop reactor (LR).

The second reactor (R2) can be a slurry reactor, like a loop reactor, as the first reactor or alternatively a gas phase reactor (GPR), preferably gas phase reactor (GPR).
15

The third reactor (R3) and fourth reactor (R4) are preferably gas phase reactors (GPR).

Such gas phase reactors (GPR) can be any mechanically mixed or fluid bed reactors. Preferably the gas phase reactors (GPR) comprise a mechanically agitated fluid bed reactor
20 with gas velocities of at least 0.2 m/sec. Thus, it is appreciated that the gas phase reactor is a fluidized bed type reactor preferably with a mechanical stirrer.

Thus in a preferred embodiment the first reactor (R1) is a slurry reactor (SR), like a loop reactor (LR), whereas the second reactor (R2), the third reactor (R3) and the fourth reactor
25 (R4) are gas phase reactors (GPR). Accordingly for the instant process at least three, preferably four polymerization reactors, namely a slurry reactor (SR), like a loop reactor (LR), a first gas phase reactor (GPR-1), a second gas phase reactor (GPR-2) and a third gas phase reactor (GPR-3) connected in series are used. If needed prior to the slurry reactor (SR) a pre-polymerization reactor is placed.

30 In another preferred embodiment the first reactor (R1) and second reactor (R2) are slurry reactors (SR), like a loop reactors (LR), whereas the third reactor (R3) and the fourth reactor (R4) are gas phase reactors (GPR). Accordingly for the instant process at least three, preferably four polymerization reactors, namely two slurry reactors (SR), like two loop
35 reactors (LR1) and (LR2), and two gas phase reactors (GPR-1) and (GPR-2) connected in

series are used. If needed prior to the first slurry reactor (SR) a pre-polymerization reactor is placed.

5 A preferred multistage process is a "loop-gas phase"-process, such as developed by Borealis A/S, Denmark (known as BORSTAR® technology) described e.g. in patent literature, such as in EP 0 887 379, WO 92/12182 WO 2004/000899, WO 2004/111095, WO 99/24478, WO 99/24479 or in WO 00/68315.

10 A further suitable slurry-gas phase process is the Spheripol® process of Basell.

Preferably, in the instant process for producing the heterophasic propylene copolymer (HECO) composition as defined above the conditions for the first reactor (R1), i.e. the slurry reactor (SR), like a loop reactor (LR), of step (a) may be as follows:

- 15 - the temperature is within the range of 50 °C to 110 °C, preferably between 60 °C and 100 °C, more preferably between 68 and 95 °C,
- the pressure is within the range of 20 bar to 80 bar, preferably between 40 bar to 70 bar,
- hydrogen can be added for controlling the molar mass in a manner known per se.

20 Subsequently, the reaction mixture from step (a) is transferred to the second reactor (R2), i.e. gas phase reactor (GPR-1), i.e. to step (c), whereby the conditions in step (c) are preferably as follows:

- the temperature is within the range of 50 °C to 130 °C, preferably between 60 °C and 100 °C,
- 25 - the pressure is within the range of 5 bar to 50 bar, preferably between 15 bar to 35 bar,
- hydrogen can be added for controlling the molar mass in a manner known per se.

30 The condition in the third reactor (R3) and the fourth reactor (R4), preferably in the second gas phase reactor (GPR-2) and third gas phase reactor (GPR-3), is similar to the second reactor (R2).

The residence time can vary in the three reactor zones.

In one embodiment of the process for producing the polypropylene the residence time in bulk reactor, e.g. loop is in the range 0.1 to 2.5 hours, e.g. 0.15 to 1.5 hours and the residence time in gas phase reactor will generally be 0.2 to 6.0 hours, like 0.5 to 4.0 hours.

- 5 If desired, the polymerization may be effected in a known manner under supercritical conditions in the first reactor (R1), i.e. in the slurry reactor (SR), like in the loop reactor (LR), and/or as a condensed mode in the gas phase reactors (GPR).

- 10 Preferably the process comprises also a prepolymerization with the catalyst system, as described in detail below, comprising a Ziegler-Natta procatalyst, an external donor and optionally a cocatalyst.

- 15 In a preferred embodiment, the prepolymerization is conducted as bulk slurry polymerization in liquid propylene, i.e. the liquid phase mainly comprises propylene, with minor amount of other reactants and optionally inert components dissolved therein.

The prepolymerization reaction is typically conducted at a temperature of 10 to 60 °C, preferably from 15 to 50 °C, and more preferably from 20 to 45 °C.

- 20 The pressure in the prepolymerization reactor is not critical but must be sufficiently high to maintain the reaction mixture in liquid phase. Thus, the pressure may be from 20 to 100 bar, for example 30 to 70 bar.

The catalyst components are preferably all introduced to the prepolymerization step.

- 25 However, where the solid catalyst component (i) and the cocatalyst (ii) can be fed separately it is possible that only a part of the cocatalyst is introduced into the prepolymerization stage and the remaining part into subsequent polymerization stages. Also in such cases it is necessary to introduce so much cocatalyst into the prepolymerization stage that a sufficient polymerization reaction is obtained therein.

30

It is possible to add other components also to the prepolymerization stage. Thus, hydrogen may be added into the prepolymerization stage to control the molecular weight of the prepolymer as is known in the art. Further, antistatic additive may be used to prevent the particles from adhering to each other or to the walls of the reactor.

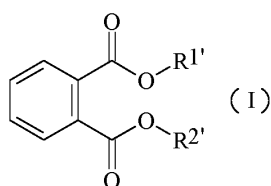
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The precise control of the prepolymerization conditions and reaction parameters is within the skill of the art.

According to the invention the heterophasic propylene copolymer (HECO) composition is
 5 obtained by a multistage polymerization process, as described above, in the presence of a catalyst system comprising as component (i) a Ziegler-Natta procatalyst which contains a trans-esterification product of a lower alcohol and a phthalic ester.

The procatalyst used according to the invention for preparing the heterophasic propylene
 10 copolymer (HECO) composition is prepared by

- a) reacting a spray crystallized or emulsion solidified adduct of MgCl_2 and a C_1 - C_2 alcohol with TiCl_4
- b) reacting the product of stage a) with a dialkylphthalate of formula (I)



- 15 wherein $\text{R}^{1'}$ and $\text{R}^{2'}$ are independently at least a C_5 alkyl under conditions where a transesterification between said C_1 to C_2 alcohol and said dialkylphthalate of formula (I) takes place to form the internal donor
- c) washing the product of stage b) or
- d) optionally reacting the product of step c) with additional TiCl_4 .

20

The procatalyst is produced as defined for example in the patent applications WO 87/07620, WO 92/19653, WO 92/19658 and EP 0 491 566. The content of these documents is herein included by reference.

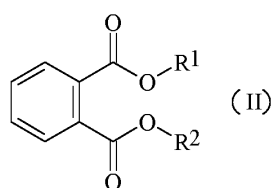
- 25 First an adduct of MgCl_2 and a C_1 - C_2 alcohol of the formula $\text{MgCl}_2 \cdot n\text{ROH}$, wherein R is methyl or ethyl and n is 1 to 6, is formed. Ethanol is preferably used as alcohol.

The adduct, which is first melted and then spray crystallized or emulsion solidified, is used as catalyst carrier.

30

In the next step the spray crystallized or emulsion solidified adduct of the formula $\text{MgCl}_2 \cdot n\text{ROH}$, wherein R is methyl or ethyl, preferably ethyl and n is 1 to 6, is contacting with TiCl_4 to form a titanized carrier, followed by the steps of

- adding to said titanised carrier
 - 5 (i) a dialkylphthalate of formula (I) with R^1 and R^2 being independently at least a C_5 -alkyl, like at least a C_8 -alkyl, or preferably
 - (ii) a dialkylphthalate of formula (I) with R^1 and R^2 being the same and being at least a C_5 -alkyl, like at least a C_8 -alkyl,
 - 10 or more preferably
 - (iii) a dialkylphthalate of formula (I) selected from the group consisting of propylhexylphthalate (PrHP), dioctylphthalate (DOP), di-iso-decylphthalate (DIDP), and ditridecylphthalate (DTDP), yet more preferably the dialkylphthalate of formula (I) is a dioctylphthalate (DOP), like di-iso-octylphthalate or diethylhexylphthalate, in particular diethylhexylphthalate,
 - 15 to form a first product,
- subjecting said first product to suitable transesterification conditions, i.e. to a temperature above 100°C , preferably between 100 to 150°C , more preferably between 130 to 150°C , such that said methanol or ethanol is transesterified with
- 20 said ester groups of said dialkylphthalate of formula (I) to form preferably at least 80 mol-%, more preferably 90 mol-%, most preferably 95 mol.-%, of a dialkylphthalate of formula (II)



- with R^1 and R^2 being methyl or ethyl, preferably ethyl,
- 25 the dialkylphthalat of formula (II) being the internal donor and
- recovering said transesterification product as the procatalyst composition (component (i)).

The adduct of the formula $\text{MgCl}_2 \cdot n\text{ROH}$, wherein R is methyl or ethyl and n is 1 to 6, is in a

30 preferred embodiment melted and then the melt is preferably injected by a gas into a cooled

solvent or a cooled gas, whereby the adduct is crystallized into a morphologically advantageous form, as for example described in WO 87/07620.

5 This crystallized adduct is preferably used as the catalyst carrier and reacted to the procatalyst useful in the present invention as described in WO 92/19658 and WO 92/19653.

As the catalyst residue is removed by extracting, an adduct of the titanised carrier and the internal donor is obtained, in which the group deriving from the ester alcohol has changed.

10 In case sufficient titanium remains on the carrier, it will act as an active element of the procatalyst.

Otherwise the titanization is repeated after the above treatment in order to ensure a sufficient titanium concentration and thus activity.

15 Preferably the procatalyst used according to the invention contains 2.5 wt.-% of titanium at the most, preferably 2.2% wt.-% at the most and more preferably 2.0 wt.-% at the most. Its donor content is preferably between 4 to 12 wt.-% and more preferably between 6 and 10 wt.-%.

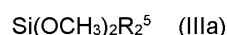
20 More preferably the procatalyst used according to the invention has been produced by using ethanol as the alcohol and dioctylphthalate (DOP) as dialkylphthalate of formula (I), yielding diethyl phthalate (DEP) as the internal donor compound.

25 Still more preferably the catalyst used according to the invention is the catalyst as described in the example section; especially with the use of dioctylphthalate as dialkylphthalate of formula (I).

30 For the production of the heterophasic propylene copolymer (HECO) composition according to the invention the catalyst system used preferably comprises in addition to the special Ziegler-Natta procatalyst an organometallic cocatalyst as component (ii).

35 Accordingly, it is preferred to select the cocatalyst from the group consisting of trialkylaluminium, like triethylaluminium (TEA), dialkyl aluminium chloride and alkyl aluminium sesquichloride.

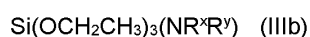
Component (iii) of the catalysts system used is an external donor represented by formula (IIIa) or (IIIb). Formula (IIIa) is defined by



wherein R^5 represents a branched-alkyl group having 3 to 12 carbon atoms, preferably a
 5 branched-alkyl group having 3 to 6 carbon atoms, or a cyclo-alkyl having 4 to 12 carbon atoms, preferably a cyclo-alkyl having 5 to 8 carbon atoms.

It is in particular preferred that R^5 is selected from the group consisting of iso-propyl, iso-butyl, iso-pentyl, tert.-butyl, tert.-amyl, neopentyl, cyclopentyl, cyclohexyl, methylcyclopentyl
 10 and cycloheptyl.

Formula (IIIb) is defined by



wherein R^x and R^y can be the same or different and represent a hydrocarbon group having 1 to
 15 12 carbon atoms.

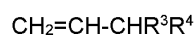
R^x and R^y are independently selected from the group consisting of linear aliphatic hydrocarbon group having 1 to 12 carbon atoms, branched aliphatic hydrocarbon group having 1 to 12 carbon atoms and cyclic aliphatic hydrocarbon group having 1 to 12 carbon
 20 atoms. It is in particular preferred that R^x and R^y are independently selected from the group consisting of methyl, ethyl, n-propyl, n-butyl, octyl, decanyl, iso-propyl, iso-butyl, iso-pentyl, tert.-butyl, tert.-amyl, neopentyl, cyclopentyl, cyclohexyl, methylcyclopentyl and cycloheptyl.

More preferably both R^x and R^y are the same, yet more preferably both R^x and R^y are an
 25 ethyl group.

More preferably the external donor is of formula (IIIa), like dicyclopentyl dimethoxy silane $[\text{Si}(\text{OCH}_3)_2(\text{cyclo-pentyl})_2]$, diisopropyl dimethoxy silane $[\text{Si}(\text{OCH}_3)_2(\text{CH}(\text{CH}_3)_2)_2]$.

30 Most preferably the external donor is dicyclopentyl dimethoxy silane $[\text{Si}(\text{OCH}_3)_2(\text{cyclo-pentyl})_2]$ (Donor D).

In a further embodiment, the Ziegler-Natta procatalyst can be modified by polymerising a vinyl compound in the presence of the catalyst system, comprising the special Ziegler-Natta
 35 procatalyst (component (i)), an external donor (component (iii)) and optionally a cocatalyst (component (iii)), which vinyl compound has the formula:



wherein R^3 and R^4 together form a 5- or 6-membered saturated, unsaturated or aromatic ring or independently represent an alkyl group comprising 1 to 4 carbon atoms, and the modified catalyst is used for the preparation of the heterophasic propylene copolymer (HECO)

5 composition according to this invention. The polymerized vinyl compound can act as an α -nucleating agent.

It is particularly preferred that the polymerized vinyl compound is the first α -nucleating agent (NU1).

10

Concerning the modification of catalyst reference is made to the international applications WO 99/24478, WO 99/24479 and particularly WO 00/68315, incorporated herein by reference with respect to the reaction conditions concerning the modification of the catalyst as well as with respect to the polymerization reaction.

15

The Article and uses

The heterophasic propylene copolymer (HECO) composition of the present invention is preferably used for the production of articles, more preferably of molded articles, yet more
20 preferably of injection molded articles or compression molded articles. Even more preferred is the use for the production of parts of car seats, paint pails, strollers, baby walkers, toys, heavy duty pails or transport packagings and the like.

The current invention also provides articles, more preferably molded articles, like injection
25 molded articles or compression molded articles, comprising, preferably comprising at least 60 wt.-%, more preferably at least 80 wt.-%, yet more preferably at least 95 wt.-%, like consisting of, the inventive heterophasic propylene copolymer (HECO) composition. Accordingly the present invention is especially directed to parts of car seats, paint pails, strollers, baby walkers, toys, heavy duty pails or transport packagings and the like,
30 comprising, preferably comprising at least 60 wt.-%, more preferably at least 80 wt.-%, yet more preferably at least 95 wt.-%, like consisting of, the inventive heterophasic propylene copolymer (HECO) composition.

The present invention is also directed to the use of the polypropylene composition (C) as
35 defined herein for the preparation of such an article.

The present invention will now be described in further detail by the examples provided below.

EXAMPLES

5

1. Measuring methods

The following definitions of terms and determination methods apply for the above general description of the invention as well as to the below examples unless otherwise defined.

MFR₂ (230 °C) is measured according to ISO 1133 (230 °C, 2.16 kg load).

10 **MFR₅ (190 °C)** is measured according to ISO 1133 (190 °C, 5.0 kg load).

Calculation of comonomer content of the second polypropylene fraction (PP2):

$$\frac{C(R2) - w(PP1) \times C(PP1)}{w(PP2)} = C(PP2)$$

wherein

- 15 **w(PP1)** is the weight fraction of the first polypropylene fraction (PP1), i.e. the product of the first reactor (R1),
- w(PP2)** is the weight fraction of the second polypropylene fraction (PP2), i.e. of the polymer produced in the second reactor (R2),
- C(PP1)** is the comonomer content [in wt.-%] of the first polypropylene fraction (PP1), i.e. of the product of the first reactor (R1),
- 20 **C(R2)** is the comonomer content [in wt.-%] of the product obtained in the second reactor (R2), i.e. the mixture of the first polypropylene fraction (PP1) and the second polypropylene fraction (PP2),
- C(PP2)** is the calculated comonomer content [in wt.-%] of the second polypropylene (PP2).

25 **Calculation** of the xylene cold soluble (XCS) content of the second polypropylene fraction (PP2):

$$\frac{XS(R2) - w(PP1) \times XS(PP1)}{w(PP2)} = XS(PP2)$$

wherein

- 30 **w(PP1)** is the weight fraction of the first polypropylene fraction (PP1), i.e. the product of the first reactor (R1),
- w(PP2)** is the weight fraction of the second polypropylene fraction (PP2), i.e. of the polymer produced in the second reactor (R2),
- XS(PP1)** is the xylene cold soluble (XCS) content [in wt.-%] of the first polypropylene fraction (PP1), i.e. of the product of the first reactor (R1),

XS(R2) is the xylene cold soluble (XCS) content [in wt.-%] of the product obtained in the second reactor (R2), i.e. the mixture of the first polypropylene fraction (PP1) and the second polypropylene fraction (PP2),

5 XS(PP2) is the calculated xylene cold soluble (XCS) content [in wt.-%] of the second polypropylene fraction (PP2).

Calculation of melt flow rate MFR_2 (230 °C) of the second polypropylene fraction (PP2):

$$MFR(PP2) = 10^{\left[\frac{\log(MFR(R2)) - w(PP1) \times \log(MFR(PP1))}{w(PP2)} \right]}$$

wherein

10 w(PP1) is the weight fraction of the first polypropylene fraction (PP1), i.e. the product of the first reactor (R1),

w(PP2) is the weight fraction of the second polypropylene fraction (PP2), i.e. of the polymer produced in the second reactor (R2),

MFR(PP1) is the melt flow rate MFR_2 (230 °C) [in g/10min] of the first polypropylene fraction (PP1), i.e. of the product of the first reactor (R1),

15 MFR(R2) is the melt flow rate MFR_2 (230 °C) [in g/10min] of the product obtained in the second reactor (R2), i.e. the mixture of the first polypropylene fraction (PP1) and the second polypropylene fraction (PP2),

MFR(PP2) is the calculated melt flow rate MFR_2 (230 °C) [in g/10min] of the second polypropylene fraction (PP2).

20 **Calculation** of comonomer content of the third polypropylene fraction (PP3):

$$\frac{C(R3) - w(R2) \times C(R2)}{w(PP3)} = C(PP3)$$

wherein

w(R2) is the weight fraction of the second reactor (R2), i.e. the mixture of the first polypropylene fraction (PP1) and the second polypropylene fraction (PP2),

25 w(PP3) is the weight fraction of the third polypropylene fraction (PP3), i.e. of the polymer produced in the third reactor (R3),

C(R2) is the comonomer content [in wt.-%] of the product of the second reactor (R2), i.e. of the mixture of the first polypropylene fraction (PP1) and second polypropylene fraction (PP2),

30 C(R3) is the comonomer content [in wt.-%] of the product obtained in the third reactor (R3), i.e. the mixture of the first polypropylene fraction (PP1), the second polypropylene fraction (PP2), and the third polypropylene fraction (PP3),

C(PP3) is the calculated comonomer content [in wt.-%] of the third polypropylene fraction (PP3).

Calculation of xylene cold soluble (XCS) content of the third polypropylene fraction (PP3):

$$\frac{XS(R3) - w(R2) \times XS(R2)}{w(PP3)} = XS(PP3)$$

5 wherein

w(R2) is the weight fraction of the second reactor (R2), i.e. the mixture of the first polypropylene fraction (PP1) and the second polypropylene fraction (PP2),

w(PP3) is the weight fraction of the third polypropylene fraction (PP3), i.e. of the polymer produced in the third reactor (R3),

10 XS(R2) is the xylene cold soluble (XCS) content [in wt.-%] of the product of the second reactor (R2), i.e. of the mixture of the first polypropylene fraction (PP1) and second polypropylene fraction (PP2),

XS(R3) is the xylene cold soluble (XCS) content [in wt.-%] of the product obtained in the third reactor (R3), i.e. the mixture of the first polypropylene fraction (PP1), the second polypropylene fraction (PP2), and the third polypropylene fraction (PP3),

15

XS(PP3) is the calculated xylene cold soluble (XCS) content [in wt.-%] of the third polypropylene fraction (PP3).

Calculation of melt flow rate MFR₂ (230 °C) of the third polypropylene fraction (PP3):

20
$$MFR(PP3) = 10^{\left[\frac{\log(MFR(R3)) - w(R2) \times \log(MFR(R2))}{w(PP3)} \right]}$$

wherein

w(R2) is the weight fraction of the second reactor (R2), i.e. the mixture of the first polypropylene fraction (PP1) and the second polypropylene fraction (PP2),

w(PP3) is the weight fraction of the third polypropylene fraction (PP3), i.e. of the polymer produced in the third reactor (R3),

25

MFR(R2) is the melt flow rate MFR₂ (230 °C) [in g/10min] of the product of the second reactor (R2), i.e. of the mixture of the first polypropylene fraction (PP1) and second polypropylene fraction (PP2),

MFR(R3) is the melt flow rate MFR₂ (230 °C) [in g/10min] of the product obtained in the third reactor (R3), i.e. the mixture of the first polypropylene fraction (PP1), the second polypropylene fraction (PP2), and the third polypropylene fraction (PP3),

30

MFR(PP3) is the calculated melt flow rate MFR₂ (230 °C) [in g/10min] of the third polypropylene fraction (PP3).

Quantification of microstructure by NMR spectroscopy

- Quantitative nuclear-magnetic resonance (NMR) spectroscopy was used to quantify the comonomer content and comonomer sequence distribution of the polymers. Quantitative $^{13}\text{C}\{^1\text{H}\}$ NMR spectra were recorded in the solution-state using a Bruker Advance III 400
- 5 NMR spectrometer operating at 400.15 and 100.62 MHz for ^1H and ^{13}C respectively. All spectra were recorded using a ^{13}C optimised 10 mm extended temperature probehead at 125°C using nitrogen gas for all pneumatics. Approximately 200 mg of material was dissolved in 3 ml of 1,2-tetrachloroethane- d_2 (TCE- d_2) along with chromium-(III)-acetylacetonate ($\text{Cr}(\text{acac})_3$) resulting in a 65 mM solution of relaxation agent in solvent
- 10 (Singh, G., Kothari, A., Gupta, V., Polymer Testing 28 5 (2009), 475). To ensure a homogenous solution, after initial sample preparation in a heat block, the NMR tube was further heated in a rotatory oven for at least 1 hour. Upon insertion into the magnet the tube was spun at 10 Hz. This setup was chosen primarily for the high resolution and quantitatively needed for accurate ethylene content quantification. Standard single-pulse excitation was
- 15 employed without NOE, using an optimised tip angle, 1 s recycle delay and a bi-level WALTZ16 decoupling scheme (Zhou, Z., Kuemmerle, R., Qiu, X., Redwine, D., Cong, R., Taha, A., Baugh, D. Winniford, B., J. Mag. Reson. 187 (2007) 225; Busico, V., Carbonniere, P., Cipullo, R., Pellecchia, R., Severn, J., Talarico, G., Macromol. Rapid Commun. 2007, 28, 1128). A total of 6144 (6k) transients were acquired per spectra.
- 20 Quantitative $^{13}\text{C}\{^1\text{H}\}$ NMR spectra were processed, integrated and relevant quantitative properties determined from the integrals using proprietary computer programs. All chemical shifts were indirectly referenced to the central methylene group of the ethylene block (EEE) at 30.00 ppm using the chemical shift of the solvent. This approach allowed comparable referencing even when this structural unit was not present. Characteristic signals
- 25 corresponding to the incorporation of ethylene were observed Cheng, H. N., Macromolecules 17 (1984), 1950).
- For polypropylene homopolymers all chemical shifts are internally referenced to the methyl isotactic pentad (mmmm) at 21.85 ppm.
- Characteristic signals corresponding to regio defects (Resconi, L., Cavallo, L., Fait, A.,
- 30 Piemontesi, F., Chem. Rev. 2000, 100, 1253; Wang, W-J., Zhu, S., Macromolecules 33 (2000), 1157; Cheng, H. N., Macromolecules 17 (1984), 1950) or comonomer were observed.
- The tacticity distribution was quantified through integration of the methyl region between 23.6-19.7 ppm correcting for any sites not related to the stereo sequences of interest
- 35 (Busico, V., Cipullo, R., Prog. Polym. Sci. 26 (2001) 443; Busico, V., Cipullo, R., Monaco, G., Vacatello, M., Segre, A.L., Macromolecules 30 (1997) 6251).

Specifically the influence of regio defects and comonomer on the quantification of the tacticity distribution was corrected for by subtraction of representative regio defect and comonomer integrals from the specific integral regions of the stereo sequences.

The isotacticity was determined at the pentad level and reported as the percentage of isotactic pentad (mmmm) sequences with respect to all pentad sequences:

$$[\text{mmmm}] \% = 100 * (\text{mmmm} / \text{sum of all pentads})$$

The presence of 2,1 erythro regio defects was indicated by the presence of the two methyl sites at 17.7 and 17.2 ppm and confirmed by other characteristic sites.

Characteristic signals corresponding to other types of regio defects were not observed (Resconi, L., Cavallo, L., Fait, A., Piemontesi, F., Chem. Rev. 2000, 100, 1253).

The amount of 2,1 erythro regio defects was quantified using the average integral of the two characteristic methyl sites at 17.7 and 17.2 ppm:

$$P_{21e} = (I_{e6} + I_{e8}) / 2$$

The amount of 1,2 primary inserted propene was quantified based on the methyl region with correction undertaken for sites included in this region not related to primary insertion and for primary insertion sites excluded from this region:

$$P_{12} = I_{CH3} + P_{12e}$$

The total amount of propene was quantified as the sum of primary inserted propene and all other present regio defects:

$$P_{total} = P_{12} + P_{21e}$$

The mole percent of 2,1 erythro regio defects was quantified with respect to all propene:

$$[21e] \text{ mol\%} = 100 * (P_{21e} / P_{total})$$

For copolymers characteristic signals corresponding to the incorporation of ethylene were observed (Cheng, H. N., Macromolecules 17 (1984), 1950).

With regio defects also observed (Resconi, L., Cavallo, L., Fait, A., Piemontesi, F., Chem. Rev. 2000, 100, 1253; Wang, W-J., Zhu, S., Macromolecules 33 (2000), 1157; Cheng, H. N., Macromolecules 17 (1984), 1950) correction for the influence of such defects on the comonomer content was required.

The comonomer fraction was quantified using the method of Wang et. al. (Wang, W-J., Zhu, S., Macromolecules 33 (2000), 1157) through integration of multiple signals across the whole spectral region in the $^{13}\text{C}\{^1\text{H}\}$ spectra. This method was chosen for its robust nature and ability to account for the presence of regio-defects when needed. Integral regions were slightly adjusted to increase applicability across the whole range of encountered comonomer contents.

For systems where only isolated ethylene in PPEPP sequences was observed the method of Wang et. al. was modified to reduce the influence of non-zero integrals of sites that are

known to not be present. This approach reduced the overestimation of ethylene content for such systems and was achieved by reduction of the number of sites used to determine the absolute ethylene content to:

$$E = 0.5(S\beta\beta + S\beta\gamma + S\beta\delta + 0.5(S\alpha\beta + S\alpha\gamma))$$

- 5 Through the use of this set of sites the corresponding integral equation becomes:

$$E = 0.5(I_H + I_G + 0.5(I_C + I_D))$$

using the same notation used in the article of Wang et. al. (Wang, W-J., Zhu, S., Macromolecules 33 (2000), 1157). Equations used for absolute propylene content were not modified.

- 10 The mole percent comonomer incorporation was calculated from the mole fraction:

$$E [\text{mol}\%] = 100 * fE$$

The weight percent comonomer incorporation was calculated from the mole fraction:

$$E [\text{wt}\%] = 100 * (fE * 28.06) / ((fE * 28.06) + ((1-fE) * 42.08))$$

- 15 The comonomer sequence distribution at the triad level was determined using the analysis method of Kakugo et al. (Kakugo, M., Naito, Y., Mizunuma, K., Miyatake, T. Macromolecules 15 (1982) 1150). This method was chosen for its robust nature and integration regions slightly adjusted to increase applicability to a wider range of comonomer contents.

Intrinsic viscosity is measured according to DIN ISO 1628/1, October 1999 (in Decalin at 135 °C).

- 20 **Density** is measured according to ISO 1183-187. Sample preparation is done by compression moulding in accordance with ISO 1872-2:2007.

The xylene solubles (XCS, wt.-%): Content of xylene cold solubles (XCS) is determined at 25 °C according ISO 16152; first edition; 2005-07-01. The part which remains insoluble is the xylene cold insoluble (XCI) fraction.

- 25 **DSC analysis, melting temperature (T_m) and crystallization temperature (T_c):** measured with a TA Instrument Q200 differential scanning calorimetry (DSC) on 5 to 7 mg samples. DSC is run according to ISO 11357 / part 3 /method C2 in a heat / cool / heat cycle with a scan rate of 10 °C/min in the temperature range of -30 to +225 °C. The crystallization temperature (T_c) is determined from the cooling step, while melting temperature (T_m) and melting enthalpy (H_m) are determined from the second heating step. The crystallinity is calculated from the melting enthalpy by assuming an H_m -value of 209 J/g for a fully crystalline polypropylene
- 30

- Flexural Modulus:** The flexural modulus was determined in 3-point-bending according to ISO 178 on injection molded specimens of 80 x 10 x 4 mm prepared in accordance with ISO 294-1:1996.
- 35

The impact strength is determined as Charpy Notched Impact Strength according to ISO 179-1 eA:2000 at +23 °C and at -20 °C on injection moulded specimens of 80 x 10 x 4 mm prepared according to EN ISO 1873-2.

5 2. Examples

A. Preparation of the heterophasic polypropylene composition

Preparation of the catalyst

First, 0.1 mol of $\text{MgCl}_2 \times 3 \text{ EtOH}$ was suspended under inert conditions in 250 ml of decane in a reactor at atmospheric pressure. The solution was cooled to the temperature of -15°C and 300 ml of cold TiCl_4 was added while maintaining the temperature at said level. Then, the temperature of the slurry was increased slowly to 20°C . At this temperature, 0.02 mol of dioctylphthalate (DOP) was added to the slurry. After the addition of the phthalate, the temperature was raised to 135°C during 90 minutes and the slurry was allowed to stand for 60 minutes. Then, another 300 ml of TiCl_4 was added and the temperature was kept at 135°C for 120 minutes. After this, the catalyst was filtered from the liquid and washed six times with 300 ml heptane at 80°C . Then, the solid catalyst component was filtered and dried.

Catalyst and its preparation concept is described in general e.g. in patent publications EP 491566, EP 591224 and EP 586390.

The catalyst was further modified (VCH modification of the catalyst). 35 ml of mineral oil (Paraffinum Liquidum PL68) was added to a 125 ml stainless steel reactor followed by 0.82 g of triethyl aluminium (TEAL) and 0.33 g of dicyclopentyl dimethoxy silane (donor D) under inert conditions at room temperature. After 10 minutes 5.0 g of the catalyst prepared above (Ti content 1.4 wt.-%) was added and after additionally 20 minutes 5.0 g of vinylcyclohexane (VCH) was added. The temperature was increased to 60°C during 30 minutes and was kept there for 20 hours. Finally, the temperature was decreased to 20°C and the concentration of unreacted VCH in the oil/catalyst mixture was analysed and was found to be 200 ppm weight.

Preparation of the heterophasic propylene copolymer (HECO) composition The heterophasic propylene copolymer (HECO) compositions were prepared in a sequential process comprising a loop (bulk) reactor (L) and three gas phase reactors (G1, G2 and G3). The reaction conditions are summarized in Table 1. The properties of the references and inventive compositions are summarized in Table 2.

35

As one can see from Table 2, the impact strength at both room and low temperature, as measured by the Charpy values at +23°C and -20°C can be significantly improved for all inventive examples, while stiffness as evaluated by flexural modulus, as well as processability, as evaluated by melt flow rate (MFR) values, both remain on a good/high level.

5

	Bimodal matrix	Bimodal matrix + bimodal elastomeric ethylene-propylene copolymer				Trimodal matrix	Trimodal matrix + unimodal elastomeric ethylene-propylene copolymer				
		Ref1	IE1	CE1	CE2		CE3	Ref2	IE2	CE4	CE5
	Prepolymerization										
	Temperature [°C]	30	30	30	30	30	30	30	30	30	30
	Pressure [bar]	55	55	55	55	55	55	55	55	55	55
	Residence time [h]	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
	H2/C3 ratio	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
	[mol/kmol]										
L	Temperature [°C]	80	80	80	80	80	80	80	80	80	80
	Pressure [bar]	55	55	55	55	55	55	55	55	55	55
	C3 feed [kg/h]	180	180	180	180	180	180	180	180	180	180
	Split [%]		30	30	30	30	30	30	30	30	30
	MFR ₂ [g/10min]	99	96	106	116	108	200	204	230	230	213
	XCS [wt.-%]	3.1	3.6	2.8	3.6	3.1	0	4.1	3.3	3.3	3.2
G1	Temperature [°C]	90	90	90	90	90	90	90	90	90	90
	Pressure [bar]	21	21	21	21	21	21	21	21	21	21
	MFR ₂ [g/10min]	70	71	69	60	65	196	203	182	182	189
	XCS [wt.-%]	2.5	2.8	2.2	3.6	3.0	0	3.5	2.7	2.7	2.6
	Temperature [°C]		80	80	80	80	80	80	80	80	80
	Pressure [bar]		18	18	18	18	18	18	18	18	18
	MFR ₂ [g/10min]		25	25	26	27	70	65	69	69	70
	C2 total [wt.-%]		7.4	6.4	6.2	5.6					
	XCS [wt.-%]		21	20	18	18	2.7	3.7	2.7	2.7	2.9
	C2 of XCS [wt.-%]		35	33	33	33					
	IV of XCS		3.6	3.6	4.4	3.9					

[illegible]

Table 1: reaction conditions

	Ref1	IE1	CE1	CE2	CE3	Ref2	IE2	CE4	CE5	CE6
MFR ₂ [g/10min]	77	17	19	22	22	85	13	20	27	23
XCS [wt.-%]		26	23	23	22		28	24	23	28
Flexural modulus [MPa]	2190	1110	1180	1220	1240	2170	1160	1310	1300	1170
Tensile strength [MPa]	2130	1100	1160	1210	1250	2120	1130	1250	1280	1140
Charpy +23 °C [kJ/m ²]	1.0	18.1	13.4	11.2	11.1	1.0	15.5	10.2	7.7	11.0
Charpy 20 °C [kJ/m ²]	0.9	6.5	5.8	5.3	5.3	0.9	7.4	5.4	4.5	6.1

Table 2: properties of the references and inventive compositions

Claims

1. Heterophasic propylene copolymer (HECO) composition comprising
- 5 a) a matrix being a propylene polymer (M), which is optionally at least bimodal, and
- b) an elastomeric ethylene-propylene copolymer (E) being dispersed in said matrix, the elastomeric ethylene-propylene copolymer (E) has an intrinsic viscosity (IV) in the range from 3.3 to 5.0 dl/g and an ethylene content in the range from 34 to 60 wt.% based on the total weight of the elastomeric ethylene-propylene copolymer (E),
- 10 wherein the xylene cold soluble fraction (XCS) is in the range from 25.0 to 50.0 wt.-%, based on the total weight of the composition.
2. The heterophasic propylene copolymer (HECO) composition according to claim 1, wherein the heterophasic propylene copolymer (HECO) composition has
- 15 i) a melt flow rate MFR_2 (230°C, 2.16 kg) determined according to ISO 1133 in the range of 10 to 30 g/10min, preferably 12 to 18 g/10 min, and/or
- ii) a flexural modulus measured according to ISO 178 on injection molded specimen of 1000 to 1400 MPa, preferably from 1050 to 1250 MPa, and/or
- 20 iii) a Charpy notched impact strength measured according to ISO 179-1eA:2000 at 23°C in the range from 14.0 to 25.0 kJ/m², preferably 15.0 to 20.0 kJ/m², and/or
- iv) Charpy notched impact strength measured according to ISO 179-1eA:2000 at -20°C in the range from 6.0 to 10.0 kJ/m², more preferably in the range from
- 25 6.2 to 9.0 kJ/m².
3. Heterophasic propylene copolymer (HECO) composition according to claim 1 or 2, wherein the propylene polymer (M) is a propylene homopolymer, preferably the propylene polymer (M) is bimodal or trimodal.
- 30 4. Heterophasic propylene copolymer (HECO) composition according to any one of the previous claims 1 to 3, wherein the propylene polymer (M) comprises at least two propylene polymer fractions (M-A) and (M-B), preferably the at least two propylene polymer fractions (M-A) and (M-B) differ from each other by the melt flow rate MFR_2 (230 °C / 2.16 kg) measured according to ISO 1133 and/or the melt flow rate MFR_2 (230 °C / 2.16 kg) measured according to ISO 1133 of the propylene polymer fraction (M-B) is lower than the melt flow rate MFR_2 (230 °C / 2.16 kg) measured according to ISO 1133 of the propylene polymer fraction (M-A).
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5. Heterophasic propylene copolymer (HECO) composition according to claim 4, wherein the propylene polymer (M) comprises two propylene polymer fractions (M-A) and (M-B), wherein
- (a) the first propylene polymer fraction (M-A) has a melt flow rate MFR_2 (230 °C / 2.16 kg) measured according to ISO 1133 in the range from 80.0 to 120.0 g/10min, preferably in the range from 85.0 to 110.0 g/10min, more preferably in the range from 90.0 to 105.0 g/10min; and/or
- (b) the second propylene polymer fraction (M-B) has a lower melt flow rate MFR_2 (230 °C / 2.16 kg) measured according to ISO 1133 than the first propylene polymer fraction (M-A) so that the melt flow rate MFR_2 (230 °C / 2.16 kg) measured according to ISO 1133 of the propylene polymer (M) is in the range from 60.0 to 90.0 g/10min, preferably in the range from 65.0 to 85.0 g/10min, more preferably in the range from 70.0 to 80.0 g/10min.
6. Heterophasic propylene copolymer (HECO) composition according to claim 4, wherein the propylene polymer (M) comprises three propylene polymer fractions (M-A), (M-B) and (M-C), wherein
- (a) the first propylene polymer fraction (M-A) has a melt flow rate MFR_2 (230 °C / 2.16 kg) measured according to ISO 1133 in the range from 200.0 to 250.0 g/10min, preferably in the range from 204.0 to 240.0 g/10min, more preferably in the range from > 204.0 to 235.0 g/10min; and/or
- (b) the second propylene polymer fraction (M-B) has a melt flow rate MFR_2 (230 °C / 2.16 kg) measured according to ISO 1133 being lower than the melt flow rate MFR_2 (230 °C / 2.16 kg) measured according to ISO 1133 of the first propylene polymer fraction (M-A) so that the mixture of (a) and (b) has a melt flow rate MFR_2 (230 °C / 2.16 kg) measured according to ISO 1133 in the range from 150.0 to 210.0 g/10min, preferably in the range from 155.0 to < 204.0 g/10min, more preferably in the range from 165.0 to < 204.0 g/10min, and/or
- (c) the third propylene polymer fraction (M-C) has a melt flow rate MFR_2 (230 °C / 2.16 kg) measured according to ISO 1133 of the mixture of (a) and (b) so that the melt flow rate MFR_2 (230 °C / 2.16 kg) measured according to ISO 1133 of the propylene polymer (M) is in the range from 50.0 to 80.0 g/10min, preferably in the range from 60.0 to 70.0 g/10min, more preferably in the range from 62.0 to 68.0 g/10min.

7. Heterophasic propylene copolymer (HECO) composition according to claims 5 or 6, wherein one of the propylene polymer fractions (M-A) and (M-B) and optional (M-C) is a propylene homopolymer, preferably each of the propylene polymer fractions (M-A), (M-B) and optional (M-C) is a propylene homopolymer, and/or each of the propylene polymer fractions (M-A), (M-B) and optional (M-C) has a xylene cold soluble (XCS) content in the range from 0 to 5 wt.-%.
8. Heterophasic propylene copolymer (HECO) composition according to any one of the previous claims 1 to 7, wherein the elastomeric ethylene-propylene copolymer (E) has a comonomer content in the range from 33 to 39 wt.-%, preferably from 33.5 to 38.5 wt.-%, determined as the comonomer content of the xylene cold soluble (XCS) fraction of the heterophasic propylene copolymer (HECO).
9. Heterophasic propylene copolymer (HECO) composition according to any one of the previous claims 1 to 8, wherein the elastomeric ethylene-propylene copolymer (E) comprises one or two elastomeric ethylene-propylene copolymer fractions (E-A) and optionally (E-B).
10. Article comprising the heterophasic propylene copolymer (HECO) composition according to any one of claims 1 to 9.
11. Article according to claim 11, being a molded article like an injection molded article or a compression molded article, such as parts of car seats, paint pails, strollers, baby walkers, toys, heavy duty pails or transport packagings.
12. Use of the heterophasic propylene copolymer (HECO) composition according to any one of the previous claims 1 to 9 for the preparation of an article according to claim 10 or 11.