We claim:

1. A propylene-butene copolymer, characterized in that the copolymer comprises from 90 to 99 mol% of propylene structural units and from 1 to 10 mol% of butene structural units, and preferably from 91 to 97 mol% of propylene structural units and from 3 to 9 mol% of butene structural units, based on the total moles of copolymer structural units, with the composition of the copolymer being determined by Fourier-Transform infrared spectroscopy analysis, and that the copolymer has a content of xylene solubles, as measured according to GB/T 24282-2009, of ≤ 4 wt%, preferably ≤ 3 wt%, wherein the propylene-butene copolymer comprises less than 0.015 wt% of a fraction having a molecular weight below 1000 g/mol, as determined by a GPC method, and wherein the copolymer has a molecular weight distribution index, Mw/Mn, as determined by gel permeation chromatography of less than 4.5.

2. The propylene-butene copolymer as claimed in claim 1, wherein the copolymer has a molecular weight distribution index, Mw/Mn, as determined by gel permeation chromatography of less than 4.

3. The propylene-butene copolymer as claimed in claim 1, wherein the propylene-butene copolymer is free of phthalate-type plasticizers.

4. A method for preparing the propylene-butene copolymer of claim 1, comprising the step of polymerizing propylene and butene in the presence of a catalyst and optional hydrogen under olefin polymerization conditions, to obtain the propylene-butene copolymer,

wherein the catalyst is a Ziegler-Natta catalyst comprising a solid catalyst component, an alkylaluminum compound and an optional external electron donor compound,

the solid catalyst component comprising a reaction product of

(i) a magnesium-containing compound;

(ii) a titanium-containing compound; and

(iii) an internal electron donor,

wherein the internal electron donor comprises a phosphate compound and a diether

compound.

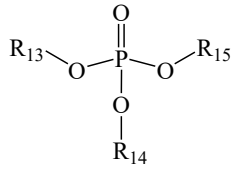
5. The method as claimed in claim 4, wherein the olefin polymerization reaction is carried out in the presence of hydrogen, wherein the hydrogen concentration on molar basis in the polymerization system is ≥ 1200 ppm, preferably in the range of from 1800 to 8000 ppm, and more preferably in the range of from 2300 to 6000 ppm.

6. The method as claimed in claim 4 or 5, further comprising conducting a precontact reaction of the solid catalyst component, the alkylaluminum compound, and the optional external electron donor compound to provide a precontacted catalyst, and after the precontact reaction and before the polymerization reaction, conducting a prepolymerization reaction using propylene monomer and/or other alpha-olefin monomer such as ethylene or butene and optionally hydrogen in the presence of the precontacted catalyst.

7. The method as claimed in any one of claims 4 to 6, wherein the propylene and the butene are used in the polymerization in amounts such that the copolymer comprises 90-99 mol% of propylene structural units and 1-10 mol% of butene structural unit, preferably 91-97 mol% of propylene structural units and 3-9 mol% of butene structural units, based on the total moles of copolymer structural units, with the composition of the copolymer being determined by Fourier-Transform infrared spectroscopy analysis.

8. The method as claimed in any one of claims 4 to 7, having at least one of the following features:

- the combined content of the phosphate compound and the diether compound is from 70 to 100 % by weight, preferably from 80 to 100 % by weight, further preferably from 90 to 100 % by weight, and most preferably 100 % by weight, based on the weight of the internal electron donor;
- the phosphate compound is at least one of those represented by formula (1),



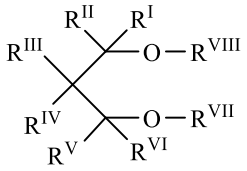
Formula (1)

wherein, R_{13}, R_{14} and R_{15} are, each independently, selected from the group consisting of C_1-C_{20} linear or branched alkyl, C_3-C_{20} cycloalkyl, C_6-C_{20} aryl, C_7-C_{20} alkaryl and C_7-C_{20} aralkyl, the hydrogen atom(s) on the benzene ring in the aryl, the alkaryl and the aralkyl being optionally

substituted by a halogen atom or a C_1-C_4 alkoxy; further preferably, R_{13}, R_{14} and R_{15} are, each independently, selected from the group consisting of C_1-C_{12} linear or branched alkyl, C_3-C_{12} cycloalkyl, C_6-C_{12} aryl, C_7-C_{12} alkaryl and C_7-C_{12} aralkyl, the hydrogen atom(s) on the benzene ring in the aryl, the alkaryl and the aralkyl being optionally substituted by a halogen atom or a C_1-C_4 alkoxy; still further preferably, R_{13}, R_{14} and R_{15} are, each independently, selected from the group consisting of C_1-C_4 linear or branched alkyl, C_3-C_6 cycloalkyl, C_6-C_8 aryl, C_7-C_8 alkaryl and C_7-C_8 aralkyl, the hydrogen atom(s) on the benzene ring in the aryl, the alkaryl and the aralkyl being optionally substituted by a halogen atom;

preferably, the phosphate compound is at least one selected from trimethyl phosphate, triethyl phosphate, tributyl phosphate, triphenyl phosphate, tris(o-, m- or p-tolyl) phosphate, tris(o-, m- or p-cumyl) phosphate, tris(o-, m- or p-methoxyphenyl) phosphate, phenyldimethyl phosphate, (o-, m- or p-tolyl) dibutyl phosphate, (o-, m- or p-cumyl) dimethyl phosphate, (o-, m- or p-cumyl) diethyl phosphate, (o-, m- or p-cumyl) dibutyl phosphate, phenyl di(o-, m- or p-tolyl) phosphate, phenyl di(o-, m- or p-cumyl) phosphate, 2,5-dimethylphenyl dibutyl phosphate, 3,5-dimethylphenyl dibutyl phosphate, 2,5-diisopropylphenyl dimethyl phosphate, 2,5-diisopropylphenyl diethyl phosphate, 2,5-di-tert-butylphenyl dimethyl phosphate and o-tolyl bis(2,5-di-tert-butylphenyl) phosphate;

- the diether compound is at least one of those represented by formula (2),



(2)

wherein, R^I, R^{II}, R^{III}, R^V, R^V and R^{VI} are the same or different, and are each independently selected from the group consisting of hydrogen, halogen atom, C_1-C_{20} linear or branched alkyl, C_3-C_{20} cycloalkyl, C_6-C_{20} aryl, C_7-C_{20} alkaryl and C_7-C_{20} aralkyl, with the R^I-R^{VI} groups being optionally linked to form a ring; R^{VII} and R^{VIII} are the same or different, and are each independently selected from the group consisting of C_1-C_{20} linear or branched alkyl, C_3-C_{20} cycloalkyl, C_6-C_{20} aryl, C_7-C_{20} alkaryl and C_7-C_{20} aralkyl;

preferably, the diether compound is at least one selected from 2-(2-ethylhexyl)-1,3-dimethoxypropane, 2-isopropyl-1,3-dimethoxypropane, 2-butyl-1,3-dimethoxypropane, 2-sec-butyl-1,3-dimethoxypropane, 2-cyclohexyl-1,3-dimethoxypropane, 2-phenyl-1,3-dimethoxypropane, 2-(2-phenylethyl)-1,3-dimethoxypropane, 2-(2-cyclohexylethyl)-1,3-dimethoxypropane, 2-(p-chlorophenyl)-1,3-dimethoxypropane, 2-(diphenylmethyl)-1,3-

dimethoxypropane, 2,2-dicyclohexyl-1,3-dimethoxypropane, 2,2-dicyclopentyl-1,3-dimethoxypropane, 2,2-diethyl-1,3-dimethoxypropane, 2,2-dipropyl-1,3-dimethoxypropane, 2,2-diisopropyl-1,3-dimethoxypropane, 2,2-dibutyl-1,3-dimethoxypropane, 2-methyl-2-propyl-1,3-dimethoxypropane, 2-methyl-2-benzyl-1,3-dimethoxypropane, 2-methyl-2-ethyl-1,3-dimethoxypropane, 2-methyl-2-isopropyl-1,3-dimethoxypropane, 2-methyl-2-phenyl-1,3-dimethoxypropane, 2-methyl-2-cyclohexyl-1,3-dimethoxypropane, 2,2-bis(2-cyclohexylethyl)-1,3-dimethoxypropane, 2-methyl-2-isobutyl-1,3-dimethoxypropane, 2-methyl-2-(2-ethylhexyl)-1,3-dimethoxypropane, 2,2-diisobutyl-1,3-dimethoxypropane, 2,2-diphenyl-1,3-dimethoxypropane, 2,2-dibenzyl-1,3-dimethoxypropane, 2,2-bis(cyclohexylmethyl)-1,3-dimethoxypropane, 2-isobutyl-2-isopropyl-1,3-dimethoxypropane, 2-(1-methylbutyl)-2-isopropyl-1,3-dimethoxypropane, 2-isopropyl-2-isopentyl-1,3-dimethoxypropane, 2-phenyl-2-isopropyl-1,3-dimethoxypropane, 2-phenyl-2-sec-butyl-1,3-dimethoxypropane, 2-benzyl-2-isopropyl-1,3-dimethoxypropane, 2-cyclopentyl-2-isopropyl-1,3-dimethoxypropane, 2-cyclopentyl-2-sec-butyl-1,3-dimethoxypropane, 2-cyclohexyl-2-isopropyl-1,3-dimethoxypropane, 2-cyclohexyl-2-sec-butyl-1,3-dimethoxypropane, 2-isopropyl-2-sec-butyl-1,3-dimethoxypropane, 2-cyclohexyl-2-cyclohexylmethyl-1,3-dimethoxypropane and 9,9-dimethoxymethylfluorene;

- the molar ratio of the phosphate compound to the diether compound is 0.02-0.28:1, preferably 0.03-0.25:1, and more preferably 0.04-0.20:1; alternatively, the molar ratio of the phosphate compound to the diether compound is 0.02-0.30: 1, preferably 0.04-0.25: 1, and more preferably 0.05-0.20: 1;

- the magnesium-containing compound is at least one of magnesium halides, magnesium alkoxides, alkoxy magnesium halides, and magnesium halide adducts;

- the titanium-containing compound is at least one of those represented by the general formulae $Ti(OR')_{3-a}Z_a$ and $Ti(OR')_{4-b}Z_b$, wherein R′ is a C_1-C_{20} alkyl, preferably a C_1-C_{12} alkyl, and more preferably a C_1-C_6 alkyl; Z is a halogen; a is an integer of 1 to 3, and b is an integer of 1 to 4;

- in the solid catalyst component, relative to one part by weight of titanium element, the content of magnesium element is from 2 to 16 parts by weight, preferably from 3 to 13 parts by weight, and more preferably from 4 to 10 parts by weight; and the content of the internal electron donor is from 2 to 16 parts by weight, preferably from 3 to 14 parts by weight, and more preferably from 4 to 12 parts by weight;

- the alkylaluminum compound is at least one of compounds represented by the general

formula $AlR_{16}R_{16}'R_{16}''$, wherein R_{16}, R_{16}' and R_{16}'' are each independently a C_1-C_8 alkyl or a halogen, and at least one of them is a C_1-C_8 alkyl, the hydrogen atom(s) on the alkyl being optionally substituted with a halogen;

- the molar ratio of aluminum in the alkylaluminum compound to titanium in the solid catalyst component is 1-1000:1, preferably 20-500: 1, and further preferably 30-200: 1;

- the molar ratio of aluminum in the alkylaluminum compound to the external electron donor compound is 1-50:1, preferably 2-20: 1, and more preferably 2-15: 1;

- the external electron donor compound is at least one of the organosilicon compounds represented by formula X,

$(R_{17})_{m'}(R_{18})_{p'}Si(OR_{19})_{q'}$ Formula X

wherein, R_{17}, R_{18} and R_{19} are each independently a C_1-C_{18} hydrocarbon group, optionally containing a halogen; m' and p' are each independently an integer of from 0 to 2, q' is an integer of from 1 to 3, and the sum of m', p' and q' is 4;

preferably, R_{17} and R_{18} are each independently a C_3-C_{10} linear or branched alkyl, a C_3-C_{10} alkenyl, a C_3-C_{10} cycloalkyl or a C_6-C_{10} aryl, optionally containing a halogen; and R_{19} is a C_1-C_{10} linear or branched alkyl, preferably a C_1-C_4 linear or branched alkyl, and more preferably a methyl group;

more preferably, the organosilicon compound is at least one selected from cyclohexylmethyldimethoxysilane, diisopropyldimethoxysilane, di-n-butyldimethoxysilane, diisobutyldimethoxysilane, diphenyldimethoxysilane, methyl-tert-butyldimethoxysilane, dicyclopentyldimethoxysilane, cyclohexyltrimethoxysilane, methyltrimethoxysilane, ethyltrimethoxysilane, tert-butyltrimethoxysilane, tert-hexyltrimethoxysilane and 2-ethylpiperidinyl-2-tert-butyldimethoxysilane;

- the temperature for the olefin polymerization reaction ranges from 10 to 150 °C, preferably from 50 to 150 °C, and more preferably from 60 to 90 °C;

- the pressure for the olefin polymerization reaction ranges from 0.01 to 10 MPa, preferably from 0.05 to 5 MPa, more preferably from 0.1 to 4 MPa, and more preferably from 1 to 4 MPa;

- the residence time of the reaction monomers and catalyst in the polymerization reactor is in a range of from 0.5 to 6 h, and preferably from 1 to 4 h;

- the temperature for the precontact reaction ranges from -10 to 30 °C, and preferably from 0 to 15 °C;

- the duration of the precontact reaction ranges from 0.05 to 30 min, and preferably from 0.1 to 10 min;

- a small amount of hydrogen gas is optionally introduced into the prepolymerization reaction;

- the temperature for the prepolymerization reaction ranges from 10 to 50 °C, preferably from 12 to 25 °C, and more preferably from 15 to 19 °C;

- the duration of the prepolymerization reaction ranges from 1 to 40 min, and preferably from 5 to 20 min.

9. Use of the propylene-butene copolymer as claimed in any one of claims 1 to 3 in packaging for food and/or healthcare products.