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(54) **PROPYLENE COPOLYMER, POLYPROPYLENE COMPOSITION, USE THEREOF, TRANSITION METAL COMPOUNDS, AND CATALYSTS FOR OLEFIN POLYMERIZATION**

PROPYLENCOPOLYMER, POLYPROPYLENZUSAMMENSETZUNG, VERWENDUNG DAVON, ÜBERGANGSMETALLVERBINDUNGEN UND KATALYSATOREN FÜR DIE OLEFINPOLYMERISATION

COPOLYMERES DE PROPYLENE, COMPOSITION DE POLYPROPYLENE, UTILISATION DE CEUX-CI, COMPOSES DE METAUX DE TRANSITION ET CATALYSEURS DESTINES A UNE POLYMERISATION OLEFINIQUE

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Description**FIELD OF THE INVENTION**

5 **[0001]** The present invention relates to a propylene/1-butene random copolymer, a polypropylene composition containing the propylene/1-butene random copolymer, a sheet, a film and an oriented film comprising the polypropylene composition, and a polypropylene composite film that includes a layer comprising the polypropylene composition.

BACKGROUND OF THE INVENTION

10 **[0002]** Polypropylenes are versatile thermoplastic molding materials with excellent properties, including high stiffness, heat resistance and transparency. On the other hand, the flexibility and impact resistance of polypropylenes are inadequate so that they are generally incorporated with soft rubber components. Although incorporation of soft rubber components compensates for the insufficient flexibility and impact resistance of polypropylenes, the resultant polypropylene compositions have lowered heat resistance. Further, such polypropylene compositions are required to have improved low-temperature heat-sealability.

15 **[0003]** Accordingly, there has been a demand for a polypropylene composition that has excellent flexibility and impact resistance as well as sufficient heat resistance and low-temperature heat-sealability.

20 **[0004]** Meanwhile, crystalline polypropylenes have excellent mechanical properties including tensile strength, stiffness, surface hardness and impact strength; optical properties including gloss and transparency; and food sanitation properties including nontoxicity and odorlessness- These properties provide wide applications particularly for food packaging purposes. However, single layer films consisting of the crystalline polypropylenes shrink at heat seal temperatures so that difficulties are caused in heat sealing such films. Therefore, the crystalline polypropylene films are generally combined with a heat-sealing layer that comprises a polymer such as a low-density polyethylene or a propylene/ethylene random copolymer.

25 **[0005]** The heat-sealing layers made from such polymers are required:

- 30 (1) to be heat-sealable at considerably lower temperatures than are the substrate films (crystalline polypropylene films);
- (2) to have high heat-sealing strength of little deterioration with time;
- (3) to have good adhesion to the substrate films;
- (4) to be as transparent as or more transparent than the substrate films;
- (5) to cause no blocking during storage;
- 35 (6) not to adhere to bag-making machines or jigs of filling and packaging machinery; and
- (7) to have superior scratch resistance.

[0006] However, traditional heat-sealing materials do not satisfy all these properties. For example, low-density polyethylene films, although heat-sealable at low temperatures, have poor heat-sealing strength, bad adhesion to the substrate films and low transparency, and are also liable to adhere to packaging jigs.

40 **[0007]** Propylene/ethylene random copolymers can meet the above properties (2) to (7) but fail to satisfy the property (1). Therefore, the polypropylene composite films that include a heat-sealing layer comprising a propylene/ethylene random copolymer have a narrow range of heat-seal temperatures. Accordingly, heat sealing of these composite films by automatic packaging or bag-making machines requires strict control of the heat seal temperatures. Other materials proposed so far for the heat-sealing materials include blends of the propylene/ethylene random copolymers with ethylene/ α -olefin copolymers. Such blends have improved low-temperature heat-sealability relative to the propylene/ethylene random copolymers, but their transparency is inferior.

45 **[0008]** The present applicant has found that a propylene/1-butene random copolymer which contains 55 to 85 wt% propylene and has a crystalline heat of fusion between 20 and 80 J/g as measured on a differential scanning calorimeter, is effectively used as a heat-sealing material because of its high transparency and excellent low-temperature heat-sealability. The present applicant has proposed a heat-sealing layer for polypropylene films that is formed from a composition which comprises the propylene/1-butene random copolymer in an amount of 50 wt% or more and an isotactic polypropylene (JP-A-S54-114887). The heat-sealing layer comprising the above composition has excellent low-temperature heat-sealability and blocking resistance, but is rather inferior in blocking and scratch resistances to the heat-sealing layers from the propylene/ethylene random copolymers. The present applicant has also proposed a composite film with excellent heat-sealability (JP-B-S61-42626); the composite film comprises an isotactic polypropylene film and a heat-sealing layer that comprises a composition containing the propylene/1-butene copolymer in an amount of 10 to 40 wt% and a crystalline propylene/ α -olefin random copolymer.

55 **[0009]** Moreover, these polypropylene films need further improvements to meet the demand for higher-speed pack-

aging. For example, excellent slip properties and blocking resistance as well as enhanced low-temperature heat-sealability are required.

[0010] JP-A-H08-238733 discloses a composite film that includes a heat-sealing layer comprising a metallocene-catalyzed propylene/1-butene copolymer and a crystalline propylene/ α -olefin random copolymer. This reference has a problem that when the propylene/1-butene copolymer has a melting point of around 70°C, crystallization rate is lowered to cause bad productivity. Also, the moldability and the appearance of the film are more deteriorated when the propylene/1-butene copolymer has a large amount.

[0011] Metallocene compounds are of much interest recently as homogenous catalysts for olefin polymerization. Olefin polymerization with use of the metallocene compounds, particularly stereoregular polymerization of α -olefins, has been studied by many since the report of isotactic polymerization by W. Kaminsky, et al. (*Angew. Chem. Int. Ed. Engl.*, 24, 507 (1985)).

[0012] In α -olefin polymerization using the metallocene compounds, it has been found that the stereoregularity and the molecular weights of resultant α -olefin polymers are widely varied by use of the compounds in which a substituent group is introduced into a cyclopentadienyl ring of a ligand or in which two cyclopentadienyl rings are bridged.

[0013] For example, propylene polymerization in the presence of a metallocene compound having a ligand in which a cyclopentadienyl ring and a fluorenyl ring are bridged, will yield stereoregular polymers such as:

syndiotactic polypropylenes when the polymerization is catalyzed by dimethylmethylene (cyclopentadienyl) (fluorenyl) zirconium dichloride (*J. Am. Chem. Soc.*, 110, 6255 (1988));

hemisotactic polypropylenes under catalysis by the above compound with introduction of a methyl group into the third position of the cyclopentadienyl ring, i.e. under catalysis by dimethylmethylene(3-methylcyclopentadienyl) (fluorenyl)zirconium dichloride (JP-A-H03-193796); and

isotactic polypropylenes under catalysis by the above compound with introduction of a tert-butyl group into the third position of the cyclopentadienyl ring, i.e. under catalysis by dimethylmethylene(3-tert-butylcyclopentadienyl) (fluorenyl)zirconium dichloride (JP-A-H06-122718). Further, dimethylmethylene(3-tert-butyl-5-methylcyclopentadienyl) (fluorenyl) zirconium dichloride can catalyze polymerization of propylene to provide higher isotacticity when tert-butyl groups are introduced into the third and sixth positions of the fluorenyl ring (i.e. dimethylmethylene(3-tert-butyl-5-methylcyclopentadienyl)(3,6-di-tert-butylfluorenyl) zirconium dichloride) (WO01/27124).

[0014] With respect to the influence on the molecular weights: dimethylmethylene(cyclopentadienyl)(fluorenyl) zirconium dichloride can produce syndiotactic polypropylenes having higher molecular weights when the bridging group between the cyclopentadienyl ring and fluorenyl ring is altered to a diphenylmethylene group (i.e. diphenylmethylene (cyclopentadienyl)(fluorenyl)zirconium dichloride) (JP-A-H02-274703);

dimethylmethylene(3-(2-adamantyl)-cyclopentadienyl) (fluorenyl)zirconium dichloride can produce isotactic-hemisotactic polypropylenes having higher molecular weights when the bridging group is altered to a diphenylmethylene group (i.e. diphenylmethylene (3-(2-adamantyl)-cyclopentadienyl) (fluorenyl) zirconium dichloride) (*Organometallics*, 21, 934 (2002)); and

dimethylmethylene(3-tert-butylcyclopentadienyl) (fluorenyl) zirconium dichloride can produce isotactic polypropylenes having higher molecular weights when a methyl group is introduced into the fifth position of the cyclopentadienyl ring (i.e. dimethylmethylene (3-tert-butyl-5-methylcyclopentadienyl) (fluorenyl) zirconium dichloride) (JP-A-2001-526730).

[0015] Contrary, polypropylenes with lower molecular weights result when substituent groups are introduced into two adjacent positions in the cyclopentadienyl ring of a catalyst component (JP-A-2001-526730 and JP-A-H10-226694); for example, dimethylmethylene (3-tert-butyl-2-methylcyclopentadienyl) (fluorenyl) zirconium dichloride and diphenylmethylene (3,4-dimethylcyclopentadienyl)(fluorenyl)zirconium dichloride can catalyze polymerization so as to give lower molecular weight polypropylenes relative to dimethylmethylene(3-tert-butyl-5-methylcyclopentadienyl) (fluorenyl)zirconium dichloride and diphenylmethylene (3-methylcyclopentadienyl)(fluorenyl)zirconium dichloride, respectively.

[0016] Meanwhile, synthesis of metallocene compounds that have a ligand in which a cyclopentadienyl group with substituent groups at two non-adjacent positions (e.g. third and fifth positions) and a fluorenyl group are bridged via an (alkyl)(aryl)methylene group or a diarylmethylene group, has been unsuccessful. This is attributed to the troublesome preparation of such ligand by the established method due to difficult reaction between a fluorene metal salt and a 1,6-diphenylfulvene derivative whose five-membered ring is substituted with such as an electron-donating hydrocarbon group. Furthermore, such selective introduction of substituent groups into two non-adjacent positions is difficult with the method disclosed in JP-A-H10-226694.

[0017] In general, the polymerization catalysts containing the metallocene compounds are required for further improvements in terms of polymerization activity, stereoregularity and molecular weight control. In particular, a polymerization catalyst that contains a metallocene compound as described in JP-A-H10-298221 can copolymerize ethylene and propylene while avoiding fouling, but the resultant copolymer has a remarkably lower molecular weight than a propylene homopolymer obtained with the catalyst.

[0018] Also, a polymerization catalyst that contains a metallocene compound as described in JP-A-H10-120733 copolymerizes ethylene and propylene to provide a higher molecular weight copolymer with no fouling. However, since this polymerization catalyst essentially requires a specific combination of an ionic compound and a metallocene compound, its versatility is rather limited.

[0019] As described above, olefin polymerization, for example copolymerization of ethylene and propylene, with these catalysts containing the metallocene compounds, has been almost unable to produce polymers having high molecular weights.

[0020] The present invention aims at solving the aforesaid problems. The present inventors have developed a novel transition metal compound useful as an olefin polymerization catalyst component that has a ligand in which a cyclopentadienyl ring with substituent groups at two non-adjacent positions and a fluorenyl ring are bridged via an aryl-substituted carbon atom, and also an olefin polymerization catalyst containing the transition metal compound. The present invention has been accomplished based on these findings.

[0021] Polyolefin resins, such as propylene block copolymers, have many applications including daily necessities, kitchenware, packaging films, home electric appliances, machine parts, electrical parts and automobile parts. These products and parts are mainly manufactured by injection molding due to high productivity. When resin compositions that contain propylene block copolymers are injection molded, circular ripples, called flow marks or tiger marks, occur on molded articles in the cross-flow direction. Noticeable flow marks on surfaces deteriorate the appearance of the molded articles so that they are concealed by painting or the like according to need. To cover up or obscure the flow marks on the molded articles obtained from the resin compositions containing propylene block copolymers, the resin compositions are injected into a high-temperature mold. However, this process requires a special mold and also the molding cycle is prolonged, causing productivity problems.

[0022] On the other hand, JP-A-H10-1573 discloses a composition comprising a metallocene-catalyzed propylene block copolymer and an α -olefin copolymer rubber. The metallocene-catalyzed propylene block copolymers have low crystallinity due to an approximate 1% of occurrence of 1, 3-insertion or 2, 1-insertion of propylene monomer. As a result, their melting points fall around 150°C, while propylene block copolymers prepared using titanium catalysts have melting points of 160°C or several degrees higher. Further, the metallocene-catalyzed propylene block copolymers have lower tensile strength and flexural strength properties and stiffness than propylene block copolymers prepared with use of titanium catalysts. Therefore, practical use of the compositions comprising the metallocene-catalyzed propylene block copolymers and α -olefin copolymer rubbers has been unrealized due to their inferior mechanical strength properties to the compositions comprising titanium-catalyzed propylene block copolymers and α -olefin copolymer rubbers.

[0023] JP-A-8 283 343 and JP-A-8 208 909 relate to polypropylenes having excellent physical properties but neither addresses the problem of securing low haze and good low-temperature heat sealability.

DISCLOSURE OF THE INVENTION

[0024] The present invention has objects of providing a propylene/1-butene random copolymer that has excellent flexibility, impact resistance, heat resistance and low-temperature heat-sealability, a polypropylene composition comprising the propylene/1-butene random copolymer, and a polypropylene composite film that can be obtained with good moldability and has superior transparency, low-temperature heat-sealability, blocking resistance and mechanical strength such as scratch resistance.

[0025] The propylene/1-butene random copolymer (PBR) according to the present invention is defined in claim 1.

[0026] The polypropylene composition (CC-1) according to the invention comprises 5 to 95 wt% of a polypropylene (PP-A) and 95 to 5 wt% of the propylene/1-butene random copolymer (PBR) defined in claim 1

[0027] The polypropylene composite film according to the present invention comprises a crystalline polypropylene layer (I) and a layer of a polypropylene composition (II) laminated on at least one surface of the crystalline polypropylene layer (I), wherein polypropylene composition (CC-2) comprises 0 to 95 wt% of a crystalline polypropylene (PP-A) and 5 to 100 wt% of a propylene/1-butene random copolymer (PBR), the propylene/1-butene random copolymer (PBR) as defined in claim 1.

[0028] The propylene/1-butene random copolymer (PBR) is preferably obtained by copolymerizing propylene and 1-butene in the presence of an olefin polymerization catalyst that comprises:

(1a) a transition metal compound,

(1b) an organoaluminum oxy-compound, and/or

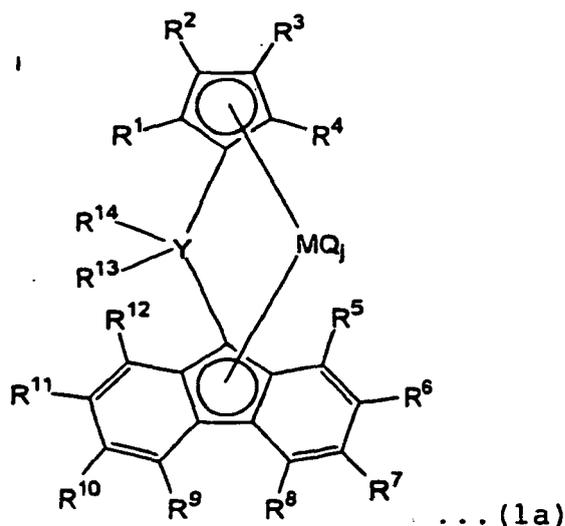
(2b) a compound capable of forming an ion pair by reacting with the transition metal compound (1a), and optionally

(c) an organoaluminum compound; the transition metal compound (1a) having the formula (1a):

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wherein R^3 is a hydrocarbon group or a silicon-containing group; R^1 , R^2 and R^4 , which may be the same or different, are each a hydrogen atom, a hydrocarbon group or a silicon-containing group; R^5 , R^6 , R^7 , R^8 , R^9 , R^{10} , R^{11} , R^{12} , R^{13} and R^{14} , which may be the same or different, are each a hydrogen atom, a hydrocarbon group or a silicon-containing group; neighboring substituent groups of R^5 to R^{12} may link together to form a ring; R^{13} and R^{14} , which may be the same or different, may link together to form a ring; M denotes a Group-4 transition metal; Y denotes a carbon atom; Q denotes a halogen atom, a hydrocarbon group, an anionic ligand or a neutral ligand capable of coordination by a lone pair of electrons, and may be the same or different when plural; and j is an integer of 1 to 4.

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[0029] The sheet or film according to the present invention comprises the polypropylene composition.

[0030] The oriented film of the present invention is obtained by orienting the sheet, film or composite film in at least one direction.

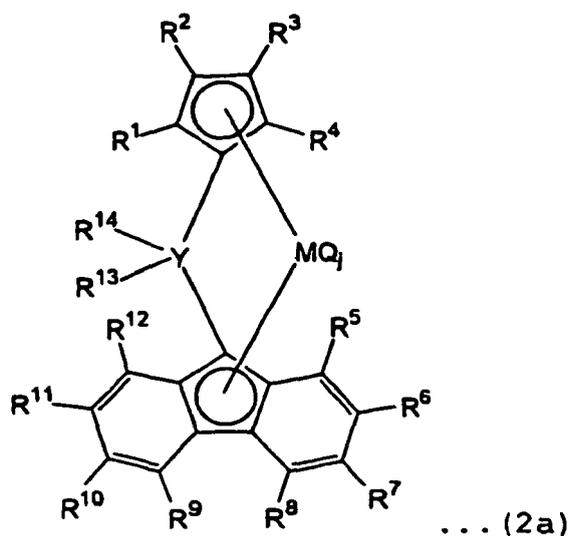
[0031] The transition metal compound used in the present invention is represented by the formula (2a):

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wherein R^1 and R^3 are each a hydrogen atom; R^2 and R^4 , which may be the same or different, are each a hydrocarbon group or a silicon-containing group; R^5 , R^6 , R^7 , R^8 , R^9 , R^{10} , R^{11} , R^{12} and R^{13} , which may be the same or different, are each a hydrogen atom, a hydrocarbon group or a silicon-containing group; neighboring substituent groups of R^5 to R^{12} may link together to form a ring; R^{14} is an aryl group; R^{13} and R^{14} , which may be the same or different, may link together to form a ring; M denotes a Group-4 transition metal; Y denotes a carbon atom; Q denotes a halogen atom, a hydrocarbon

group, an anionic ligand or a neutral ligand capable of coordination by a lone pair of electrons, and may be the same or different when plural; and j is an integer of 1 to 4.

[0032] The transition metal compound (3a) used in the present invention has the formula (2a) in which both R¹³ and R¹⁴ are aryl groups.

[0033] The olefin polymerization catalyst used in the present invention comprises (A) the transition metal compound (2a) or (3a) and (B) at least one compound selected from:

(B-1) an organometallic compound,

(B-2) an organoaluminum oxy-compound, and

(B-3) a compound capable of forming an ion pair by reacting with the transition metal compound (A).

BRIEF DESCRIPTION OF THE DRAWING

[0034]

Fig. 1 is a schematic cross-sectional view of the unoriented sheet prepared in Example 1b.

PREFERRED EMBODIMENTS OF THE INVENTION

[0035] Hereinbelow, the polypropylene composition according to the present invention will be described in detail. The polypropylene composition comprises a polypropylene described below and a specific propylene/1-butene copolymer.

[0036] The polypropylene (PP-A) for use in the present invention may be selected from numerous conventional polypropylenes. The polypropylene may be a homopolypropylene or a propylene random copolymer that contains a small amount, for example 10 mol% or less, preferably less than 5 mol%, of units derived from an olefin other than the propylene.

In the present invention, the propylene random copolymer is preferably used.

[0037] The other olefins for the propylene random copolymer include α -olefins of 2 to 20 carbon atoms other than the propylene, such as ethylene, 1-butene, 1-pentene, 1-hexene, 1-heptene, 1-octene, 1-decene, 1-dodecene, 1-hexadecene and 4-methyl-1-pentene.

[0038] For use in the present invention, polypropylenes produced by the conventional process using a known solid titanium catalyst component are suitable. Metallocene-catalyzed polypropylenes may also be favorably used.

[0039] The polypropylene (PP-A) of the present invention desirably has a melting point (T_m) of 100 to 165°C, preferably 120 to 165°C. The polypropylene desirably has a melting point which is within the above range and is higher than that of a later-described propylene/1-butene random copolymer (PBR) when incorporated to the polypropylene composition. The melting point (T_{mA}) of the polypropylene (PP-A) is higher than the melting point (T_{mB}) of the propylene/1-butene random copolymer (PBR) by 10 to 100°C, preferably by 20 to 90°C.

[0040] The polypropylene (PP-A) desirably has a melt flow rate (MFR) (ASTM D1238, 230°C, 2.16 kg load) generally of 0.1 to 400 g/10 min, preferably 0.5 to 100 g/10 min, and has a molecular weight distribution (M_w/M_n) of above 3, desirably from 4 to 15.

[0041] The polypropylene (PP-A) generally has a hardness higher than that of the propylene/1-butene random copolymer (PBR).

[0042] The polypropylene composite film according to the invention includes a substrate layer (1) that is formed from a crystalline polypropylene (PP-B). The crystalline polypropylene of the present invention may be selected from those polypropylenes commonly used for films. Preferably, the crystalline polypropylene (PP-B) has an isotactic index (I.I.) (content of boiling n-heptane insolubles) of 75% or more, preferably from 75 to 99%, a density of 0.89 to 0.92 g/cm³, and a melt index (otherwise a melt flow rate) at 230°C of 0.1 to 10 dg/min. Although the crystalline polypropylene used herein is generally a homopolypropylene, a propylene random copolymer that contains a small amount, for example 5 mol% or less, of units derived from an olefin other than the propylene may be used without adversely affecting the objects of the present invention. The olefins include α -olefins of 2 to 20 carbon atoms other than the propylene, such as ethylene, 1-butene, 1-pentene, 1-hexene, 1-heptene, 1-octene, 1-decene, 1-dodecene, 1-hexadecene and 4-methyl-1-pentene.

The crystalline polypropylene (PP-B) for use in the present invention may be obtained by the conventional process using a known solid titanium catalyst component or a metallocene catalyst component. The crystalline polypropylene (PP-B) may optionally contain additives, including heat stabilizers, ultraviolet light absorbers, anti-blocking agents, slip-agents and antistatic agents.

[0043] In the present invention, the polypropylene (PP-B) may be selected from a number of known polypropylenes for forming the crystalline polypropylene layer. The polypropylene may be a homopolypropylene or a propylene random copolymer that contains a small amount, for example 10 mol% or less, preferably less than 5 mol%, of units derived from an olefin other than the propylene. The homopolypropylene may be preferably used in the present invention due to its high stiffness.

[0044] The propylene/1-butene random copolymer (PBR) contains propylene-derived units in an amount of 60 to 90 mol%, preferably 65 to 88 mol%, more preferably 70 to 85 mol%, and still more preferably 70 to 75 mol%, and 1-butene-derived units in an amount of 10 to 40 mol%, preferably 12 to 35 mol%, more preferably 15 to 30 mol%, and still more preferably 25 to 30 mol%. The propylene/1-butene random copolymer of the present invention has a melting point of 75°C or below and its crystallization rate (1/2 crystallization time) at 45°C is 10 minutes or less, preferably 7 minutes or less.

[0045] The propylene/1-butene random copolymer (PBR) may contain additional constituent units derived from an olefin other than the propylene and the 1-butene, for example ethylene-derived constituent units, in an amount of 10 mol% or less.

(2) Stereoregularity (triad tacticity, mm fraction) of propylene/1-butene random copolymer (PBR)

[0046] The stereoregularity of the propylene/1-butene copolymer (PBR) can be evaluated based on the triad tacticity (mm fraction).

[0047] The mm fraction is defined as a proportion of methyl groups branched in the same direction in a triad sequence of propylene units that are head-to-tail bonded to form a zigzag structure. The mm fraction is determined from a ¹³C-NMR spectrum as described below.

[0048] Determination of the mm fraction of the propylene/1-butene random copolymer (PBR) from a ¹³C-NMR spectrum involves investigation of peaks assigned to (i) a triad sequence of propylene units that are head-to-tail bonded and (ii) a triad sequence of propylene and butene units that are head-to-tail bonded with a propylene unit in the middle (the second unit).

[0049] The mm fraction is obtained from peak intensities assigned to side-chain methyl groups in the second units (propylene units) of the triad sequences (i) and (ii). Details are as follows.

[0050] An NMR sample is prepared in a sample tube by completely dissolving the propylene/1-butene random copolymer (PBR) in a lock solvent consisting of hexachlorobutadiene and a small amount of deuterated benzene, and the ¹³C-NMR spectrum of the resultant sample is recorded with complete proton decoupling at 120°C. Measurement conditions are such that the flip angle is 45° and the pulse intervals are at least 3.4 T₁ (T₁ is the longest spin-lattice relaxation time for the methyl group). The methylene and methine groups have shorter T₁ than the methyl group, so that all the carbons in the sample will have a magnetization recovery rate of 99% or more under the above conditions. The chemical shift is based on tetramethylsilane as the standard: the peak assigned to the methyl group carbon of the third unit in a pentad sequence (mmmm) of head-to-tail bonded propylene units is set to 21.593 ppm, and other peaks of carbon are determined relative to that peak.

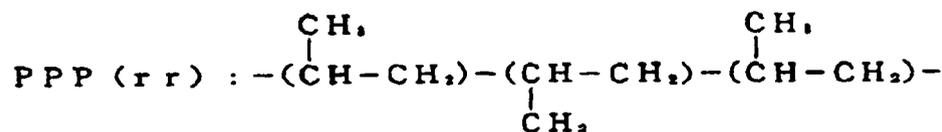
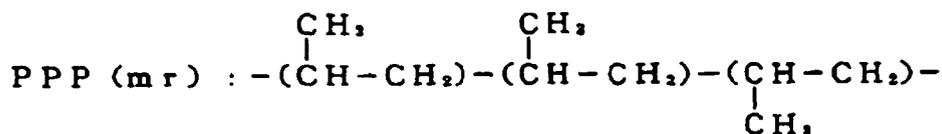
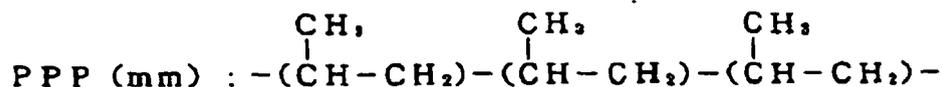
[0051] With respect to the ¹³C-NMR spectrum of the propylene/1-butene random copolymer (PBR) recorded as above, the carbons in the side-chain methyl groups of the propylene units give peaks in an approximate range of 19.5 to 21.9 ppm: the first peak range about 21.0 to 21.9 ppm, the second peak range about 20.2 to 21.0 ppm and the third peak range about 19.5 to 20.2 ppm.

[0052] In these peak ranges, the carbons in the side-chain methyl groups in the second unit (propylene unit) of the head-to-tail bonded triad sequences (i) and (ii) give peaks as shown in Table 1.

Table 1

Chemical shift		Peak range of methyl group carbons (19.5-21.9 ppm)		
		First range 21.0-21.9 ppm	Second range 20.2-21.0 ppm	Third range 19.5-20.2 ppm
	Sequence (i)	PPP (mm)	PPP (mr)	PPP (rr)
Head-to-tail bonding type	Sequence (ii)	PPB (mm) BPB (mm)	PPB (mr) BPB (mr) PPB (rr) BPB (rr)	

[0053] In the table, P denotes a constituent unit derived from propylene, and B denotes that derived from 1-butene. Of the triad sequences (i) and (ii) with head-to-tail bondings given in Table 1, the triad sequence (i) consisting of three propylene units PPP (mm), PPP (mr) and PPP (rr) are illustrated below in terms of zigzag structures as a result of branched methyl groups. These illustrations for mm, mr and rr bondings also apply to the triad sequence (ii) that contains butene unit (s) (PPB and BPB).



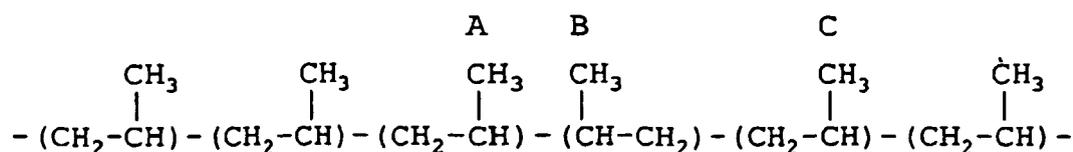
[0054] In the first range, the methyl groups in the second propylene unit of the mm-bonded triad sequences PPP, PPB and BPB give resonance peaks. The second range shows resonance peaks of the methyl groups in the second propylene unit of the mr-bonded triad sequences PPP, PPB and BPB, and those assigned to the methyl groups in the second propylene unit of the rr-bonded triad sequences PPB and BPB.

[0055] In the third range, the methyl group in the second propylene unit of the rr-bonded triad sequence PPP gives a resonance peak. Therefore, the triad tacticity (mm fraction) of the propylene/1-butene random copolymer (PBR) is a proportion (percentage) of the area of the peaks appearing in the range of 21.0 to 21.9 ppm (first range) relative to the total (100%) of the areas of the peaks found within 19.5 to 21.9 ppm (methyl group carbon range) according to measurement by ¹³C-NMR spectroscopy (hexachlorobutadiene solution, with tetramethylsilane as the reference) based on the side-chain methyl groups in the second propylene unit of (i) the triad sequence of head-to-tail bonded propylene units or in the second propylene unit of (ii) the triad sequence of propylene and butene units that are head-to-tail bonded with a propylene unit as the second unit. Specifically, the mm fraction may be derived from the following formula (1):

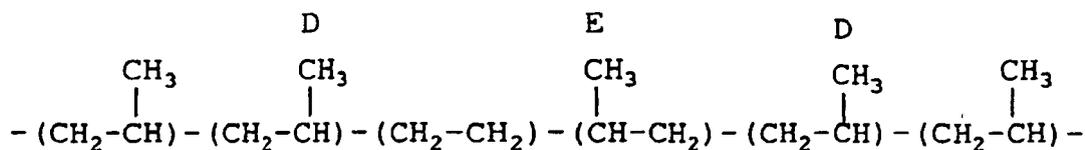
$$\text{mm fraction (\%)} = \frac{\text{Intensities of methyl groups} \\ [\text{PPP (mm)} + \text{PPB (mm)} + \text{BPB (mm)}]}{\text{Intensities of methyl groups} \\ [\text{PPP (mm)} + \text{PPB (mm)} + \text{BPB (mm)} + \\ \text{PPP (mr)} + \text{PPB (mr)} + \text{BPB (mr)} + \\ \text{PPP (rr)} + \text{PPB (rr)} + \text{BPB (rr)}]} \times 100 \quad \dots (1)$$

[0056] The mm fraction of the propylene/1-butene random copolymer (PBR) obtained as described above ranges from 85 to 97.5%, preferably from 87 to 97%, and more preferably from 90 to 97%. Importantly, the mm fraction in the present invention should fall in a moderate range. The mm fraction within the above range enables the copolymer to have a lower melting point while containing a relatively large amount of propylene. The propylene/1-butene random copolymer (PBR) contains, in addition to the head-to-tail bonded triad sequences (i) and (ii), a minor amount of structural units that include irregularly arranged units as illustrated in the formulae (iii), (iv) and (v). The side-chain methyl groups in these other propylene units also show peaks within the above methyl group carbon range (19.5 to 21.9 ppm).

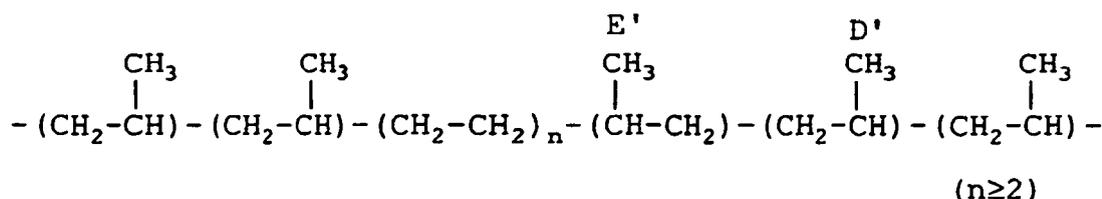
Formula (iii)



Formula (iv)



Formula (v)



[0057] In the methyl groups in these structural units as illustrated in formulae (iii), (iv) and (v), the methyl group carbons A and B give resonance peaks at 17.3 ppm and 17.0 ppm respectively, outside the first to third peak ranges (19.5 to 21.9 ppm). Since the carbons A and B are not involved in forming the triad propylene sequence with head-to-tail bondings, the triad tacticity (mm fraction) should be calculated excluding them.

[0058] Meanwhile, the peaks assigned to the methyl group carbons C, D and D' appear in the second range, and those assigned to the methyl group carbons E and E' appear in the third range.

[0059] Therefore, the first to third peak ranges for the methyl group carbons show the peaks assigned to the PPE-methyl group (the side-chain methyl group in a propylene-propylene-ethylene sequence) (near 20.7 ppm), the EPE-methyl group (the side-chain methyl group in an ethylene-propylene-ethylene sequence) (near 19.8 ppm), the methyl group C, the methyl group D, the methyl group D', the methyl group E and the methyl group E'.

[0060] As described above, the peak ranges of methyl group carbons show peaks assigned to the methyl groups in sequences other than the head-to-tail bonded triad sequences (i) and (ii). Therefore, these peaks are calibrated as described below for determination of the mm fraction by the above formula.

[0061] The peak area of the PPE-methyl group can be obtained from the peak area of the PPE-methine group (resonance near 30.6 ppm). The peak area of the EPE-methyl group can be obtained from the peak area of the EPE-methine group (resonance near 32.9 ppm).

[0062] The peak area of the methyl group C can be obtained from the peak area of the adjacent methine group (resonance near 31.3 ppm). The peak area of the methyl group D is half the combined peak areas of α , β methylene carbons in the structural unit (iv) (resonance near 34.3 ppm and near 34.5 ppm). The peak area of the methyl group D' can be obtained from the peak area of the methine group (resonance near 33.3 ppm) adjacent to the methyl group E' in the structural unit (v).

[0063] The peak area of the methyl group E can be obtained from the peak area of the adjacent methine carbon (resonance near 33.7 ppm). The peak area of the methyl group E' can be obtained from the peak area of the adjacent methine carbon (resonance near 33.3 ppm).

[0064] Accordingly, subtracting these peak areas from the total peak areas in the second and third ranges gives an area of the peaks assigned to the methyl groups in the head-to-tail bonded triad propylene sequences (i) and (ii).

[0065] The peak area of the methyl groups in the head-to-tail bonded triad propylene sequences (i) and (ii) provided by the above subtraction is put in the above formula to work out the mm fraction.

[0066] The carbon peaks found in the spectrum may be assigned by reference to the literature "Polymer, 30, 1350 (1989)".

(3) Intrinsic viscosity $[\eta]$

[0067] The propylene/1-butene random copolymer (PBR) has an intrinsic viscosity $[\eta]$ of 0.1 to 12 dl/g, preferably 0.5 to 10 dl/g, and more preferably 1 to 5 dl/g as measured in decalin at 135°C.

(4) Molecular weight distribution

[0068] The propylene/1-butene random copolymer (PBR) has a molecular weight distribution (M_w/M_n) of 3 or less, preferably from 1.8 to 3.0, and more preferably from 1.9 to 2.5 according to measurement by gel permeation chromatography (GPC).

(5) Randomness

[0069] The propylene/1-butene random copolymer (PBR) has a parameter value B, indicative of randomness of distributed monomer sequences, of 0.9 to 1.3, preferably 0.95 to 1.25, and more preferably 0.95 to 1.2.

[0070] The parameter value B has been proposed by B. D. Coleman and T. G. Fox (J. Polym. Sci., A1, 3183 (1963)), and can be defined as follows:

$$B = P_{12} / (2P_1 \cdot P_2)$$

wherein P_1 and P_2 are fractions of first and second monomers respectively, and P_{12} is a proportion of (first monomers) - (second monomer) sequences relative to all the dyad monomer sequences.

[0071] When the B-value is 1, the Bernoulli's statistics applies. When the B-value is smaller than 1 ($B < 1$), the copolymer is arranged in the form of block chains. On the other hand, when the B-value is greater than 1 ($B > 1$), the copolymer is arranged in the form of alternate chains. When the B-value is 2 ($B = 2$), the copolymer is an alternating copolymer. (6)

[0072] The propylene/1-butene random copolymer (PBR) has a melting point (T_m) of 40 to 120°C, preferably 50 to 100°C, and more preferably 55 to 90°C as measured on a differential scanning calorimeter. The melting point (T_m) and the content (M) of 1-butene constituent units (mol%) satisfy the relation of:

$$146 \exp(-0.022M) \geq T_m \geq 125 \exp(-0.032M),$$

preferably

$$146 \exp(-0.024M) \geq T_m \geq 125 \exp(-0.032M),$$

and more preferably

$$146 \exp(-0.0265M) \geq T_m \geq 125 \exp(-0.032M).$$

[0073] When the melting point and the butene content have the above correlation, the copolymer can display a lowered melting point while containing a relatively large amount of propylene. As a result, the copolymer can display higher crystallization rate in spite of a low melting point.

[0074] The propylene/1-butene random copolymer (PBR) according to the present invention may contain a minor amount of irregularly bonded (irregularly arranged) propylene units based on 2,1-insertion or 1,3-insertion in the propylene sequence.

[0075] When polymerized, the propylene generally forms a head-to-tail bonded sequence with 1,2-insertion (in which the methylene groups bond a catalyst), but 2,1-insertion or 1,3-insertion also unusually occurs. The propylene units having 2,1-insertion or 1,3-insertion form irregularly arranged units as represented by the formulae (iii), (iv) and (v). As with the stereoregularity, the proportion of the propylene units with 2,1-insertion and 1,3-insertion relative to the polymer structural units may be determined from the following formula based on data obtained from a ^{13}C -NMR spectrum with reference to the literature "Polymer, 30, 1350 (1989)".

[0076] The proportion of the irregularly arranged propylene units based on 2,1-insertion can be obtained from the formula:

$$\text{Proportion of irregularly arranged units with 2,1-insertion} = \frac{\{0.5I\alpha\beta(\text{structures (iii) and (v)}) + 0.25I\alpha\beta(\text{structure (iv)})\}}{I\alpha\alpha + I\alpha\beta(\text{structures (iii) and (v)}) + 0.5(I\alpha\gamma + I\alpha\beta(\text{structure (iv)}) + I\alpha\delta)} \times 100$$

[0077] When determination of the peak areas of $\alpha\beta$, etc. is difficult owing to the overlapping peaks, calibration can be made with the peaks of carbon that have corresponding areas.

[0078] The propylene/1-butene random copolymer (PBR) according to the present invention may contain the irregularly bonded propylene units in terms of 2, 1-insertion in an amount of 0.01% or above, specifically about 0.01 to 1.0% relative to all the propylene structural units.

[0079] The proportion of the irregularly arranged propylene units based on 1, 3-insertion in the propylene/1-butene random copolymer (PBR) can be obtained from the peak of $\beta\gamma$ peak (resonance near 27.4 ppm).

[0080] The propylene/1-butene random copolymer according to the present invention may contain the irregularly bonded propylene units based on 1,3-insertion in an amount of 0.05% or less.

[0081] An exemplary process for the production of the propylene/1-butene random copolymer (PBR) according to the present invention will be given below.

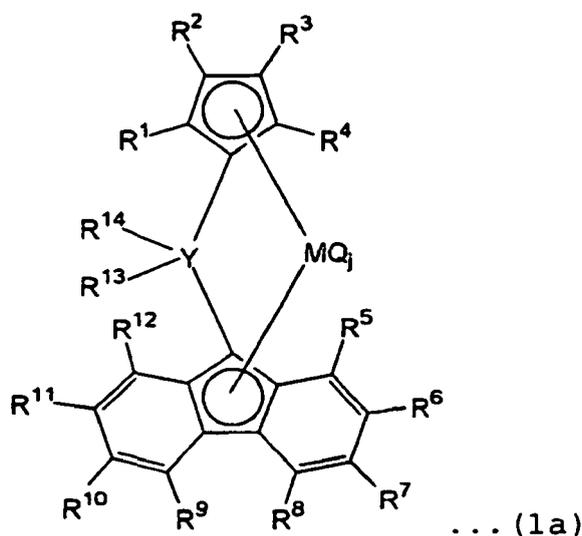
[0082] The propylene/1-butene random copolymer (PBR) may be prepared by copolymerizing propylene and 1-butene in the presence of an olefin polymerization catalyst that comprises:

a transition metal compound (1a), and at least one compound selected from:

an organoaluminum oxy-compound, and/or

a compound capable of forming an ion pair by reacting with the transition metal compound (1a), and an organoaluminum compound.

[0083] The above transition metal compound (1a) has the formula (1a):



wherein R^3 is a hydrocarbon group or a silicon-containing group; R^1 , R^2 and R^4 , which may be the same or different, are each a hydrogen atom, a hydrocarbon group or a silicon-containing group; R^5 , R^6 , R^7 , R^8 , R^9 , R^{10} , R^{11} , R^{12} , R^{13} and R^{14} , which may be the same or different, are each a hydrogen atom, a hydrocarbon group or a silicon-containing group; neighboring substituent groups of R^5 to R^{12} may link together to form a ring; R^{13} and R^{14} , which may be the same or different, may link together to form a ring; M denotes a Group-4 transition metal; Y denotes a carbon atom; Q denotes a halogen atom, a hydrocarbon group, an anionic ligand or a neutral ligand capable of coordination by a lone

pair of electrons, and may be the same or different when plural; and j is an integer of 1 to 4.

[0084] Preferably, R¹ in the transition metal compound (1a) of the formula (1a) is a hydrocarbon group or a silicon-containing group.

[0085] Exemplary compounds having the formula (1a) include bridged metallocene compounds with C₁ symmetry, such as isopropylidene(3-tert-butylcyclopentadienyl)(fluorenyl) zirconium dichloride, isopropylidene (3-tert-butylcyclopentadienyl)(2,7-di-tert-butylfluorenyl) zirconium dichloride, isopropylidene (3-tert-butylcyclopentadienyl)(3,6-di-tert-butylfluorenyl) zirconium dichloride, isopropylidene (3-tert-butylcyclopentadienyl) (octamethyloctahydridodibenzofluorenyl)zirconium dichloride, diphenylmethylene (3-tert-butylcyclopentadienyl)(fluorenyl)zirconium dichloride, diphenylmethylene (3-tert-butylcyclopentadienyl)(2,7-di-tert-butylfluorenyl) zirconium dichloride, diphenylmethylene (3-tert-butylcyclopentadienyl)(3,6-di-tert-butylfluorenyl) zirconium dichloride, diphenylmethylene (3-tert-butylcyclopentadienyl) (octamethyloctahydridodibenzofluorenyl)zirconium dichloride, cyclohexylidene (3-tert-butylcyclopentadienyl)(fluorenyl) zirconium dichloride, 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[0086] The polypropylene composition (CC-1) according to the present invention contains the aforesaid polypropylene (PP-A) in an amount of 5 to 95 wt%, preferably 20 to 95 wt%, and more preferably 40 to 90 wt%, and the propylene/1-butene random copolymer (PBR) in an amount of 95 to 5 wt%, preferably 80 to 5 wt%, and more preferably 60 to 10 wt%.

[0087] The polypropylene composition (CC-2) of the present invention contains the crystalline polypropylene (PP-A) in an amount of 0 to 95 wt%, preferably 5 to 95 wt%, and more preferably 20 to 95 wt%, and the propylene/1-butene random copolymer (PBR) in an amount of 5 to 100 wt%, preferably 5 to 95 wt%, and more preferably 5 to 80 wt%.

[0088] The polypropylene compositions (CC-1) and (CC-2) may be prepared by known processes for the production of resin compositions. For example, the polypropylene (PP-A) and the propylene/1-butene random copolymer (PBR) may be melt kneaded.

[0089] The polypropylene compositions (CC-1) and (CC-2) of the present invention may contain additives or other resins in addition to the polypropylene and the propylene/1-butene copolymer without adversely affecting the objects of the invention.

[0090] The additives include nucleating agents, antioxidants, hydrochloric acid absorbers, heat stabilizers, light stabilizers, ultraviolet light absorbers, lubricants, anti-blocking agents, antistatic agents, flame-retardants, pigments, dyes, dispersants, copper inhibitors, neutralizing agents, foaming agents, plasticizers, anti-foaming agents, crosslinking agents, flow modifiers such as peroxides, and weld strength improvers.

[0091] Additives, including those listed above, that are conventionally used for the polyolefin resins may be employed without limitation.

[0092] The antioxidants include phenol-based, sulfur-based and phosphorous-based antioxidants. The phenol-based antioxidants include phenols, such as 2,6-di-tert-butyl-p-cresol, stearyl (3,3-dimethyl-4-hydroxybenzyl) thioglycolate, stearyl-β-(4-hydroxy-3,5-di-tert-butylphenol)propionate, distearyl-3,5-di-tert-butyl-9-hydroxybenzyl phosphonate, 2,4,6-tris(3',5'-di-tert-butyl-4'-hydroxybenzylthio)-1,3,5-triazine, distearyl (4-hydroxy-3-methyl-5-tert-butylbenzyl)malonate, 2,2'-methylenebis(4-methyl-6-tert-butylphenol), 4,4'-methylenebis(2,6-di-tert-butylphenol), 2,2'-methylenebis[6-(1-methylcyclohexyl)p-cresol], bis[3,5-bis[4-hydroxy-3-tert-butylphenyl]butyric acid] glycol ester, 4,4'-butylidenebis(6-tert-butyl-m-cresol), 1,1,3-tris(2-methyl-4-hydroxy-5-tert-butylphenyl)butane, bis[2-tert-butyl-4-methyl-6-(2-hydroxy-3-tert-butyl-5-methylbenzyl)phenyl] terephthalate, 1,3,5-tris (2,6-dimethyl-3-hydroxy-4-tert-butyl)benzylisocyanurate, 1,3,5-tris (3,5-di-tert-butyl-4-hydroxybenzyl)-2,4,6-trimethylbenzene, tetrakis[methylene-3-(3,5-di-tert-butyl-4-hydroxyphenyl) propionate]methane, 1,3,5-tris(3,5-di-tert-butyl-4-hydroxybenzyl)isocyanurate, 1,3,5-tris[(3,5-di-tert-butyl-4-hydroxyphenyl) propionyloxyethyl]isocyanurate, 2-octylthio-4,6-di(4-hydroxy-3,5-di-tert-butyl)phenoxy-1,3,5-triazine and 4,4'-thiobis(6-tert-butyl-m-cresol); and polyhydric phenol/carbonic acid oligoesters, such as carbonic acid oligoesters (e.g.,

polymerization degrees of 2 to 10) of 4,4'-butylidenebis(2-tert-butyl-5-methylphenol).

[0093] The sulfur-based antioxidants include dialkyl thiodipropionates such as dilauryl, dimyristyl and distearyl thiodipropionates; and esters (for example, pentaerythritoltetralauryl thiopropionate) formed between alkyl thiopropionic acids such as butyl, octyl, lauryl and stearyl thiopropionic acids and polyhydric alcohols such as glycerol, trimethylolethane,

trimethylolpropane, pentaerythritol and trishydroxyethyl isocyanurate.

[0094] The phosphorous-based antioxidants include trioctyl phosphite, trilauryl phosphite, tridecyl phosphite, octyl-diphenyl phosphite, tris(2,4-di-tert-butylphenyl) phosphite, triphenyl phosphite, tris(butoxyethyl) phosphite, tris(nonylphenyl) phosphite, distearyl pentaerythritol diphosphite, tetra(tridecyl)-1,1,3-tris(2-methyl-5-tert-butyl-4-hydroxyphenyl) butane diphosphite, tetra(C₁₂₋₁₅ alkyls)-4,4'-isopropylidenediphenyl diphosphite, tetra(tridecyl)-4,4'-butylidenebis(3-methyl-6-tert-butylphenol) diphosphite, tris(3,5-di-tert-butyl-4-hydroxyphenyl) phosphite, tris(mono- and di-nonylphenyls) phosphite, hydrogenated-4,4'-isopropylidenediphenol polyphosphite, bis(octylphenyl)·bis[4,4'-butylidenebis(3-methyl-6-tert-butylphenol)]·1,6-hexanediol diphosphite, phenyl·4,4'-isopropylidenediphenol·pentaerythritol diphosphite, bis(2,4-di-tert-butylphenyl)pentaerythritol diphosphite, bis(2,6-di-tert-butyl-4-methylphenyl) pentaerythritol diphosphite, tris[4,4'-isopropylidenebis(2-tert-butylphenol)] phosphite, phenyl·diisodecyl phosphite, di(nonylphenyl)pentaerythritol diphosphite, tris(1,3-di-stearoyloxyisopropyl) phosphite, 4,4'-isopropylidenebis(2-tert-butylphenol)·di(nonylphenyl) phosphite, 9,10-di-hydro-9-oxa-9-oxa-10-phosphaphenanthrene-10-oxide and tetrakis(2,4-di-tert-butylphenyl)-4,4'-biphenylene diphosphonite.

[0095] Other antioxidants include 6-hydroxychromane derivatives, such as α -, β -, γ - and δ -tocopherols and mixtures thereof, 2,5-dimethyl substitution product, 2,5,8-trimethyl substitution product and 2,5,7,8-tetramethyl substitution product of 2-(4-methyl-penta-3-enyl)-6-hydroxychroman, 2,2,7-trimethyl-5-tert-butyl-6-hydroxychroman, 2,2,5-trimethyl-7-tert-butyl-6-hydroxychroman, 2,2,5-trimethyl-6-tert-butyl-6-hydroxychroman and 2,2-dimethyl-5-tert-butyl-6-hydroxychroman.

[0096] Exemplary hydrochloric acid absorbers include double compounds represented by $M_xAl_y(OH)_{2x+3y-2z}(A)_z \cdot aH_2O$ (wherein M is Mg, Ca or Zn; A is an anion other than the hydroxyl group; x, y and z are each a positive number; and a is 0 or a positive number), such as $Mg_6Al_2(OH)_{16}CO_3 \cdot 4H_2O$, $Mg_6Al_2(OH)_{20}CO_3 \cdot 5H_2O$, $Mg_5Al_2(OH)_{14}CO_3 \cdot 4H_2O$, $Mg_{10}Al_2(OH)_{22}(CO_3)_2 \cdot 4H_2O$, $Mg_6Al_2(OH)_{16}HPO_4 \cdot 4H_2O$, $Ca_6Al_2(OH)_{16}CO_3 \cdot 4H_2O$, $Zn_6Al_2(OH)_{16}CO_3 \cdot 4H_2O$, $Zn_6Al_2(OH)_{16}SO_4 \cdot 4H_2O$, $Mg_6Al_2(OH)_{16}SO_3 \cdot 4H_2O$ and $Mg_6Al_2(OH)_{12}CO_3 \cdot 3H_2O$.

[0097] The light stabilizers include hydroxybenzophenones, such as 2-hydroxy-4-methoxybenzophenone, 2-hydroxy-4-n-octoxybenzophenone, 2,2'-di-hydroxy-4-methoxybenzophenone and 2,4-dihydroxybenzophenone; benzotriazoles, such as 2-(2'-hydroxy-3'-tert-butyl-5'-methylphenyl)-5-chlorobenzotriazole, 2-(2'-hydroxy-3',5'-di-tert-butylphenyl)-5-chlorobenzotriazole, 2-(2'-hydroxy-5'-methylphenyl)benzotriazole and 2-(2'-hydroxy-3',5'-di-tert-amylphenyl)benzotriazole; benzoates, such as phenyl salicylate, p-tert-butylphenyl salicylate, 2,4-di-tert-butylphenyl-3,5-di-tert-butyl-4-hydroxybenzoate and hexadecyl-3,5-di-tert-butyl-4-hydroxybenzoate; nickel compounds, such as 2,2'-thiobis(4-tert-octylphenol) nickelate, [2,2'-thiobis(4-tert-octylphenolato)]-n-butylamine nickelate and (3,5-di-tert-butyl-4-hydroxybenzyl)monoethyl phosphonate nickelate; substituted acrylonitriles, such as α -cyano- β -methyl- β -(p-methoxyphenyl)methyl acrylate; oxalic acid diamides, such as N'-2-ethylphenyl-N-ethoxy-5-tert-butylphenyloxalic diamide and N-2-ethylphenyl-N'-2-ethoxyphenyloxalic diamide; and hindered amine compounds, such as bis(2,2,6,6-tetramethyl-4-piperidine)sebacate, poly[[(6-(1,1,3,3-tetramethylbutyl)imino)-1,3,5-triazine-2,4-diyl]{4-(2,2,6,6-tetramethylpiperidyl) imino}hexamethylene] and a condensate of 2-(4-hydroxy-2,2,6,6-tetramethyl-1-piperidyl)ethanol and dimethyl succinate.

[0098] The lubricants include aliphatic hydrocarbons, such as paraffin waxes, polyethylene waxes and polypropylene waxes; higher fatty acids, such as capric acid, lauric acid, myristic acid, palmitic acid, margaric acid, stearic acid, arachidic acid and behenic acid, and metal salts thereof, such as lithium salts, calcium salts, sodium salts, magnesium salt and potassium salts thereof; aliphatic alcohols, such as palmityl alcohols, cetyl alcohols and stearyl alcohols; aliphatic amides, such as caproic amides, caprylic amides, capric amides, lauric amides, myristic amides, palmitic amides, stearic amides and erucic amides; esters of aliphatic compounds and alcohols; and fluorine compounds, such as fluoroalkylcarboxylic acids, metal salts thereof and metal salts of fluoroalkylsulfonic acids.

[0099] The anti-blocking agents include fine particles of inorganic compounds, such as silica, alumina, alumina silicate and diatomaceous earth; and fine particles of organic compounds, such as polyethylenes, crosslinked polyethylenes, polymethyl methacrylates and crosslinked polymethyl methacrylates.

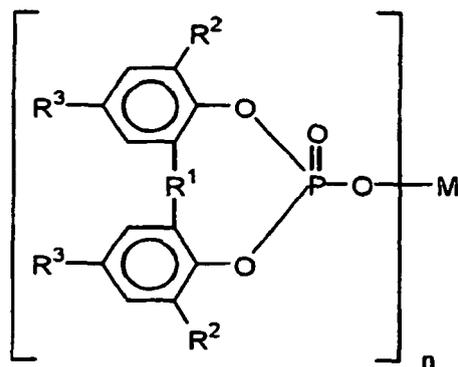
[0100] The polypropylene composition may contain these additives in amounts between 0.0001 and 10 wt%. These additives enable the polypropylene composition of the present invention to provide molded articles that have further improved property balance, durability, paintability, printability, scratch resistance and molding processability.

[0101] As described earlier, the polypropylene composition of the present invention may contain a nucleating agent. Herein, various nucleating agents known in the art may be used without limitation. Particularly, aromatic phosphates, dibenzylidene sorbitols and other nucleating agents given below are preferable nucleating agents.

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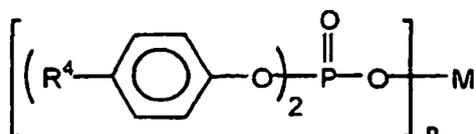
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[0102] In the formula immediately above, R¹ is an oxygen atom, a sulfur atom or a hydrocarbon group of 1 to 10 carbon atoms; R² and R³, which may be the same or different, are each a hydrogen atom or a hydrocarbon group of 1 to 10 carbon atoms; R² s, R³ s, or R² and R³ may link together to form a ring; M is a metal atom having a valency of 1 to 3; and n is an integer of 1 to 3.

[0103] The nucleating agents having this formula include sodium-2,2'-methylene-bis(4,6-di-t-butylphenyl)phosphate, sodium-2,2'-ethylidene-bis(4,6-di-t-butylphenyl)phosphate, lithium-2,2'-methylene-bis(4,6-di-t-butylphenyl)phosphate, lithium-2,2'-ethylidene-bis(4,6-di-t-butylphenyl)phosphate, sodium-2,2'-ethylidene-bis(4-i-propyl-6-t-butylphenyl) phosphate, lithium-2,2'-methylenebis(4-methyl-6-t-butylphenyl)phosphate, lithium-2,2'-methylene-bis(4-ethyl-6-t-butylphenyl) phosphate, calcium-bis[2,2'-thiobis(4-methyl-6-t-butylphenyl)phosphate], calcium-bis[2,2'-thiobis(4-ethyl-6-t-butylphenyl)phosphate], calcium-bis[2,2'-thiobis(4,6-di-t-butylphenyl)phosphate], magnesium-bis[2,2'-thiobis(4,6-di-t-butylphenyl)phosphate], magnesium-bis[2,2'-thiobis(4-t-octylphenyl)phosphate], sodium-2,2'-butylidene-bis(4,6-di-methylphenyl)phosphate, sodium-2,2'-butylidene-bis(4,6-di-t-butylphenyl)phosphate, sodium-2,2'-t-octylmethylene-bis(4,6-di-methylphenyl) phosphate, sodium-2,2'-t-octylmethylene-bis(4,6-di-t-butylphenyl)phosphate, calcium-bis-(2,2'-methylene-bis(4,6-di-t-butylphenyl)phosphate), magnesium-bis[2,2'-methylene-bis(4,6-di-t-butylphenyl) phosphate], barium-bis[2,2'-methylene-bis(4,6-di-t-butylphenyl)phosphate], sodium-2,2'-methylenebis(4-methyl-6-t-butylphenyl)phosphate, sodium-2,2'-methylene-bis(4-ethyl-6-t-butylphenyl) phosphate, sodium(4,4'-dimethyl-5,6'-di-t-butyl-2,2'-biphenyl)phosphate, calcium-bis[(4,4'-dimethyl-6,6'-di-t-butyl-2,2'-biphenyl)phosphate], sodium-2,2'-ethylidene-bis(4-m-butyl-6-t-butylphenyl) phosphate, sodium-2,2'-methylene-bis(4,6-di-methylphenyl)phosphate, sodium-2,2'-methylene-bis(4,6-di-ethylphenyl)phosphate, potassium-2,2'-ethylidene-bis(4,6-di-t-butylphenyl) phosphate, calcium-bis[2,2'-ethylidene-bis(4,6-di-t-butylphenyl)phosphate], magnesium-bis[2,2'-ethylidene-bis(4,6-di-t-butylphenyl)phosphate], barium-bis[2,2'-ethylidene-bis(4,6-di-t-butylphenyl) phosphate], aluminum-tris[2,2'-methylene-bis(4,6-di-t-butylphenyl) phosphate], aluminum-tris[2,2'-ethylidene-bis(4,6-di-t-butylphenyl)phosphate] and mixtures thereof. Of these, sodium-2,2'-methylene-bis(4,6-di-t-butylphenyl)phosphate is preferable.

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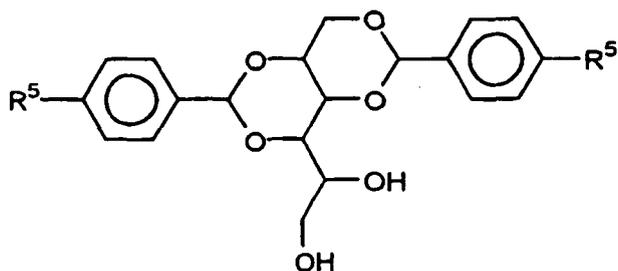
[0104] In the formula immediately above, R⁴ is a hydrogen atom or a hydrocarbon group of 1 to 10 carbon atoms; M is a metal atom having a valency of 1 to 3; and n is an integer of 1 to 3.

[0105] The nucleating agents having this formula include sodium-bis(4-t-butylphenyl)phosphate, sodium-bis(4-methylphenyl)phosphate, sodium-bis(4-ethylphenyl)phosphate, sodium-bis(4-i-propylphenyl)phosphate, sodium-bis(4-t-octylphenyl)phosphate, potassium-bis(4-t-butylphenyl)phosphate, calcium-bis(4-t-butylphenyl)phosphate, magnesium-bis(4-t-butylphenyl)phosphate, lithium-bis(4-t-butylphenyl)phosphate, aluminum-bis(4-t-butylphenyl)phosphate, and mixtures thereof. Of these, sodium-bis(4-t-butylphenyl)phosphate is preferable.

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[0106] In the formula immediately above, each R⁵ is a hydrogen atom or a hydrocarbon group of 1 to 10 carbon atoms.

15 [0107] The nucleating agents having this formula include 1,3,2,4-dibenzylidene sorbitol, 1,3-benzylidene-2,4-p-methylbenzylidene sorbitol, 1,3-benzylidene-2,4-p-ethylbenzylidene sorbitol, 1,3-p-methylbenzylidene-2,4-benzylidene sorbitol, 1,3-p-ethylbenzylidene-2,4-benzylidene sorbitol, 1,3-p-methylbenzylidene-2,4-p-ethylbenzylidene sorbitol, 1,3,2,4-di(p-methylbenzylidene)sorbitol, 1,3,2,4-di(p-ethylbenzylidene)sorbitol, 1,3,2,4-di(p-n-propylbenzylidene)sorbitol, 1,3,2,4-di(p-i-propylbenzylidene)sorbitol, 1,3,2,4-di(p-n-butylbenzylidene)sorbitol, 1,3,2,4-di(p-s-butylbenzylidene)sorbitol, 1,3,2,4-di(p-t-butylbenzylidene)sorbitol, 1,3,2,4-di(2',4'-dimethylbenzylidene)sorbitol, 1,3,2,4-di(p-methoxybenzylidene)sorbitol, 1,3,2,4-di(p-ethoxybenzylidene)sorbitol, 1,3-benzylidene-2,4-p-chlorobenzylidene sorbitol, 1,3-p-chlorobenzylidene-2,4-benzylidene sorbitol, 1,3-p-chlorobenzylidene-2,4-p-methylbenzylidene sorbitol, 1,3-p-chlorobenzylidene-2,4-p-ethylbenzylidene sorbitol, 1,3-p-methylbenzylidene-2,4-p-chlorobenzylidene sorbitol, 1,3-p-ethylbenzylidene-2,4-p-chlorobenzylidene sorbitol, 1,3, 2, 4-di(p-chlorobenzylidene)sorbitol and mixtures thereof. Of these, 1,3,2,4-dibenzylidene sorbitol, 1,3,2,4-di(p-methylbenzylidene)sorbitol, 1,3,2,4-di(p-ethylbenzylidene)sorbitol, 1,3-p-chlorobenzylidene-2,4-p-methylbenzylidene sorbitol and mixtures thereof are preferable.

20 [0108] Other nucleating agents include metallic salts of aromatic carboxylic acids and of aliphatic carboxylic acids, such as aluminum benzoate, aluminum p-t-butylbenzoate, sodium adipate, sodium thiophenecarboxylate and sodium pyrrolecarboxylate.

30 [0109] Inorganic compounds such as talc are also employable as the nucleating agents. The polypropylene compositions (CC-1) and (CC-2) may each contain the nucleating agent in an amount of 0.001 to 10 wt%, preferably 0.01 to 5 wt%, and particularly preferably 0.1 to 3 wt%.

[0110] Examples of the other resins include thermoplastic resins and thermosetting resins, including α -olefin homopolymers such as polyethylene and poly-1-butene, α -olefin copolymers, copolymers of α -olefins and vinyl monomers, modified olefin polymers such as maleic anhydride-modified polypropylenes, nylons, polycarbonates, ABS resins, polystyrenes, polyvinyl chlorides, polyphenylene oxides, petroleum resins and phenolic resins.

35 [0111] Further, the polypropylene compositions (CC-1) and (CC-2) of the present invention may each contain an inorganic filler. Examples thereof include:

40 powdery fillers, including natural silicic acids and silicates such as fine powder talc, kaolinite, calcined clay, pyrophyllite, sericite and wollastonite; carbonates such as precipitated calcium carbonate, ground calcium carbonate and magnesium carbonate; hydroxides such as aluminum hydroxide and magnesium hydroxide; oxides such as zinc oxide, zinc white and magnesium oxide; and synthetic silicic acids and silicates such as hydrated calcium silicate, hydrated aluminum silicate, hydrated silicic acid and silicic anhydride;

45 flaky fillers, including mica;

fibrous fillers, including basic magnesium sulfate whisker, calcium titanate whisker, aluminum borate whisker, sepiolite, PMF (processed mineral fiber), xonotlite, potassium titanate and ellestadite; and

balloon fillers, including glass balloon and fly ash balloon.

50 [0112] Of these fillers, fine powder talc is preferably used in the present invention. Particularly preferably, the fine powder talc has a mean particle diameter of 0.2 to 3 μ m, especially 0.2 to 2.5 μ m.

[0113] Desirably, the fine powder talc contains particles whose mean diameter is 5 μ m or more in an amount of 10 wt% or less, preferably 8 wt% or less. The mean particle diameter of the talc can be measured by liquid-phase precipitation.

55 [0114] The talc for use in the present invention preferably has a mean aspect ratio (ratio of longitudinal or lateral length to thickness) of 3 or more, particularly 4 or more.

[0115] The inorganic fillers of the present invention, particularly talc, may be surface treated prior to use, which is not compulsory. The surface treatment can be carried out chemically, for example, using treating agents such as silane coupling agents, higher fatty acids, metal salts of fatty acids, unsaturated organic acids, organic titanates, resin acids

and polyethylene glycols or physically.

[0116] The surface-treated inorganic fillers, such as talc, enable the polypropylene composition to exhibit excellent weld strength, paintability and molding processability.

[0117] The inorganic fillers as mentioned above may be used in combination of two or more kinds. If necessary, in the present invention, organic fillers such as high styrenes, lignins and reclaimed rubbers may be used together with the inorganic fillers.

[0118] The polypropylene composition (CC-1) of the present invention exhibits excellent heat resistance and low-temperature heat-sealability as well as adequate flexibility and impact resistance. The polypropylene composition may be favorably used to produce, in addition to the sheet or film as disclosed in the present invention, injection molded articles such as containers, stretch-blow molded articles and containers for retort pouch foods that have improved impact resistance.

[0119] The polypropylene composition (CC-1) of the present invention has other various applications, including home electric appliance parts such as housings and washing machine tubs; automobile interior parts such as trims, interior panels and column covers; automobile exterior parts such as fenders, bumpers, side moles, mudguards and mirror covers; and ordinary miscellaneous goods.

[0120] The propylene/1-butene random copolymer (PBR) described above may be partially or completely modified with an unsaturated carboxylic acid or an anhydride thereof. The modified propylene/1-butene random copolymer can exhibit enhanced overlap packaging properties and adhesion to metals.

[0121] The sheet or film obtained from the polypropylene composition according to the present invention has a thickness of 1 to 2000 μm) preferably 2 to 1500 μm .

[0122] The sheet or film obtainable from the polypropylene composition exhibits excellent flexibility, impact resistance, transparency, low-temperature heat-sealability, anti-blocking properties, and mechanical strength such as scratch resistance. Therefore, it can be suitably employed as transparent and flexible sheets, and as sealant films.

[0123] The sheet or film of the present invention may be produced by the known production method for polyolefin sheets or films. Exemplary processes include extrusion, such as cast film extrusion and inflation film extrusion, and calendaring. Since the polypropylene composition of the present invention has an excellent balance between the melting point and the crystallization rate, it can provide sheets or films having good appearance by the above processes with good productivity.

[0124] The laminate according to the present invention comprises a crystalline polypropylene layer (I) and a polypropylene resin composition layer (II) disposed on at least one surface of the crystalline polypropylene layer (I). The crystalline polypropylene layer (I) ranges in thickness from 1 to 2000 μm , preferably from 2 to 1500 μm , and the polypropylene composition layer (II) has a thickness of 0.1 to 200 μm , preferably 0.2 to 150 μm .

[0125] The laminate of the present invention has excellent transparency, low-temperature heat-sealability, anti-blocking properties, and mechanical strength such as scratch resistance. Therefore, it can be suitably employed as sealant films.

[0126] The laminate of the present invention may be produced by the known production process for polyolefin laminates. Preferred processes include coextrusion. Since the polypropylene composition of the present invention has an excellent balance between the melting point and the crystallization rate, it can provide sheets or films having good appearance by the above process with good productivity.

[0127] The sheet, film or laminate (otherwise composite film) according to the present invention may be unoriented or oriented in at least one direction. The unoriented or oriented sheet or film may be corona treated on either or both surfaces by the conventional method.

[0128] The oriented film may be favorably used as sealant films and shrink films. Particularly, the oriented film obtainable from the polypropylene composition of the present invention is ideal as a shrink film because of its excellent shrink properties. Orientation may be carried out by conventional methods for stretching polyolefin films. Specific examples include rolling orientation, tentering and tubular orientation. The draw ratio is 1.5 to 30 times, and generally 3 to 15 times.

[0129] The sheet, film, laminate, oriented film and oriented laminate of the present invention may be used singly or, for the purpose of higher barrier properties and rigidity, may be laminated with another film. The laminating films include polyolefin films, polystyrene films, polyester films, polyamide films, oriented films thereof, laminates of polyolefin films and gas-barrier films, aluminum foils, paper and metallized films. Preferred laminating processes include extrusion laminating and dry laminating.

[0130] The sheet, film and laminate comprising the polypropylene composition of the present invention have excellent transparency, flexibility, anti-blocking properties and heat-sealability. Particularly, they can be heat sealed even at lower temperatures to provide a wide range of heat seal temperatures. Also, they can be heat sealed with sufficient strength. The film remains unchanged in terms of heat seal strength even after long storage, so that stable heat sealing is ensured. The film obtained by orienting the sheet, film or laminate according to the present invention exhibits superior heat sealability, blocking resistance and shrink properties.

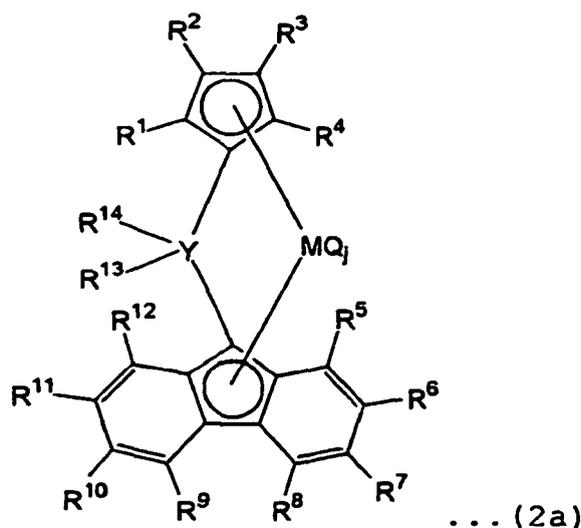
[0131] The sheet, film, laminate, oriented film and oriented laminate (otherwise composite film) of the present invention

have exceptional transparency, scratch resistance and blocking resistance to allow high-speed packaging. Therefore, they are favorably used in, for example, food packaging, packed wrapping and fiber packaging.

[0132] Hereinbelow, descriptions will be sequentially presented for the transition metal compound of the formula (2a), exemplary preferred transition metal compounds, production process for the transition metal compound, preferred embodiment of the transition metal compound in olefin polymerization catalysts, and olefin polymerization in the presence of an olefin polymerization catalyst containing the transition metal compound of the present invention.

Transition metal compound

[0133] A transition metal compound used in the present invention has the formula (2a):

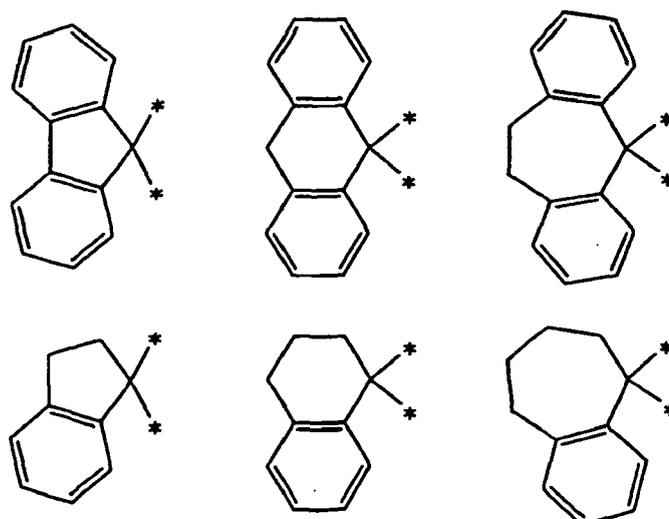


wherein R^1 and R^3 are each a hydrogen atom; R^2 and R^4 , which may be the same or different, are each a hydrocarbon group or a silicon-containing group; and R^5 , R^6 , R^7 , R^8 , R^9 , R^{10} , R^{11} , R^{12} and R^{13} , which may be the same or different, are each a hydrogen atom, a hydrocarbon group or a silicon-containing group.

[0134] The hydrocarbon groups include linear hydrocarbon groups such as methyl, ethyl, n-propyl, allyl, n-butyl, n-pentyl, n-hexyl, n-heptyl, n-octyl, n-nonyl and n-decanyl groups; branched hydrocarbon groups such as isopropyl, tert-butyl, amyl, 3-methylpentyl, 1,1-diethylpropyl, 1,1-dimethylbutyl, 1-methyl-1-propylbutyl, 1,1-dipropylbutyl, 1,1-dimethyl-2-methylpropyl and 1-methyl-1-isopropyl-2-methylpropyl groups; saturated cyclic hydrocarbon groups such as cyclopentyl, cyclohexyl, cycloheptyl, cyclooctyl, norbornyl and adamantyl groups; unsaturated cyclic hydrocarbon groups such as phenyl, tolyl, naphthyl, biphenyl, phenanthryl and anthracenyl groups; saturated hydrocarbon groups substituted with unsaturated cyclic hydrocarbon groups, such as benzyl, cumyl, 1,1-diphenylethyl and triphenylmethyl groups; and heteroatom-containing hydrocarbon groups such as methoxy, ethoxy, phenoxy, furyl, N-methylamino, N,N-dimethylamino, N-phenylamino, pyrrol and thienyl groups.

[0135] The silicon-containing groups include trimethylsilyl, triethylsilyl, dimethylphenylsilyl, diphenylmethylsilyl and triphenylsilyl groups. Neighboring substituent groups of R^5 to R^{12} may link together to form a ring. Examples of the substituted fluorenyl group include benzofluorenyl, dibenzofluorenyl, octahydrodibenzofluorenyl, octamethyloctahydrodibenzofluorenyl and octamethyltetrahydrodicyclopentafluorenyl groups.

[0136] R^{14} is an aryl group. Examples thereof include the above-mentioned unsaturated cyclic hydrocarbon groups, saturated hydrocarbon groups substituted with unsaturated cyclic hydrocarbon groups, and heteroatom-containing unsaturated cyclic hydrocarbon groups such as furyl, pyrrol and thienyl groups. R^{13} and R^{14} may be the same or different and may link together to form a ring. Examples of such substituent groups include:

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*: Links with cyclopentadienyl groups and fluorenyl groups

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[0137] In the formula (2a), R^2 and R^4 , substituent groups to the cyclopentadienyl ring, are preferably hydrocarbon groups of 1 to 20 carbon atoms. Examples of the hydrocarbon groups of 1 to 20 carbon atoms include the aforementioned hydrocarbon groups. More preferably, R^2 is a bulky substituent group such as tert-butyl, adamantyl or triphenylmethyl group, and R^4 is a sterically smaller substituent group than R^2 , such as methyl, ethyl or n-propyl group. As used herein, "sterically smaller" means that the substituent group has a smaller volume.

[0138] Of the substituent groups R^5 to R^{12} to the fluorenyl rings in the formula (2a), arbitrary two or more groups of R^6 , R^7 , R^{10} and R^{11} are preferably hydrocarbon groups of 1 to 20 carbon atoms. Examples of the hydrocarbon groups of 1 to 20 carbon atoms include the aforesaid hydrocarbon groups. For the purpose of easy synthesis of a ligand, these groups are preferably symmetrical: R^6 and R^{11} are the same groups and R^7 and R^{10} are the same groups. In one of such preferred embodiments, R^6 and R^7 form an aliphatic ring (AR-1) and R^{10} and R^{11} form an aliphatic ring (AR-2) identical to the aliphatic ring (AR-1).

[0139] Referring to the formula (2a), Y bridging the cyclopentadienyl and fluorenyl rings is a carbon atom. The substituent groups R^{13} and R^{14} to Y are preferably both aryl groups having 6 to 20 carbon atoms. These substituent groups may be the same or different, and may link together to form a ring. Exemplary aryl groups of 6 to 20 carbon atoms include the above-mentioned unsaturated cyclic hydrocarbon groups, saturated hydrocarbon groups substituted with unsaturated cyclic hydrocarbon groups, and heteroatom-containing unsaturated cyclic hydrocarbon groups. R^{13} and R^{14} may be the same or different, and may link together to form a ring. Preferred examples thereof include fluorenylidene, 10-hydroanthracenyliidene and dibenzocycloheptadienyliidene groups.

[0140] In the formula (2a), M denotes a Group-4 transition metal, such as Ti, Zr or Hf; Q denotes a halogen atom, a hydrocarbon group, an anionic ligand or a neutral ligand capable of coordination by a lone pair of electrons, and may be the same or different when plural; and j is an integer of 1 to 4. When j is 2 or greater, Q may be the same or different. The halogens include fluorine, chlorine, bromine and iodine. Examples of the hydrocarbon group are as described above. Exemplary anionic ligands include alkoxy groups such as methoxy, tert-butoxy and phenoxy groups; carboxylate groups such as acetate and benzoate groups; and sulfonate groups such as mesylate and tosylate groups. The neutral ligands capable of coordination by a lone pair of electrons include organophosphorus compounds such as trimethylphosphine, triethylphosphine, triphenylphosphine and diphenylmethylphosphine; and ethers such as tetrahydrofuran, diethylether, dioxane and 1,2-dimethoxyethane. Preferably, at least one Q is the halogen atom or alkyl group.

Exemplary preferred transition metal compounds

[0141] Preferred transition metal compounds for the present invention include diphenylmethylene (3, 5-dimethyl-cyclopentadienyl) (fluorenyl) zirconium dichloride, diphenylmethylene (3,5-dimethyl-cyclopentadienyl) (2,7-di-tert-butylfluorenyl) zirconium dichloride, diphenylmethylene (3, 5-dimethyl-cyclopentadienyl) (3, 6-di-tert-butylfluorenyl)zirconium dichloride, diphenylmethylene (3, 5-dimethyl-cyclopentadienyl) (octamethyloctahydrodibenzofluorenyl)zirconium dichloride, diphenylmethylene(3-tert-butyl-5-methyl-cyclopentadienyl) (fluorenyl) zirconium dichloride, diphenylmethylene (3-

nyl)methylene (3-tert-butyl-5-methyl-cyclopentadienyl) (3, 6-di-tert-butylfluorenyl) zirconium dichloride, (p-tolyl) (phenyl) methylene(3-tert-butyl-5-methylcyclopentadienyl) (octamethyloctahydrodibenzofluorenyl) zirconium dichloride, dibenzylmethylene (3-tert-butyl-5-methyl-cyclopentadienyl) (fluorenyl) zirconium dichloride, dibenzylmethylene (3-tert-butyl-5-methyl-cyclopentadienyl) (2,7-di-tert-butylfluorenyl) zirconium dichloride, dibenzylmethylene(3-tert-butyl-5-methyl-cyclopentadienyl) (3,6-di-tert-butylfluorenyl)zirconium dichloride, dibenzylmethylene(3-tert-butyl-5-methyl-cyclopentadienyl) (octamethyloctahydrodibenzofluorenyl) zirconium dichloride, fluorenylidene(3-tert-butyl-5-methyl-cyclopentadienyl) (fluorenyl) zirconium dichloride, fluorenylidene (3-tert-butyl-5-methyl-cyclopentadienyl) (2,7-di-tert-butylfluorenyl) zirconium dichloride, fluorenylidene(3-tert-butyl-5-methyl-cyclopentadienyl) (3,6-di-tert-butylfluorenyl)zirconium dichloride, fluorenylidene(3-tert-butyl-5-methyl-cyclopentadienyl) (octamethyloctahydrodibenzofluorenyl)zirconium dichloride, diphenylmethylene(3-tert-butyl-5-methyl-cyclopentadienyl) (fluorenyl)zirconium dimethyl, diphenylmethylene (3-tert-butyl-5-methyl-cyclopentadienyl) (2,7-di-tert-butylfluorenyl) zirconium dimethyl, diphenylmethylene(3-tert-butyl-5-methyl-cyclopentadienyl) (3, 6-di-tert-butylfluorenyl) zirconium dimethyl, diphenylmethylene(3-tert-butyl-5-methyl-cyclopentadienyl) (octamethyloctahydrodibenzofluorenyl) zirconium dimethyl, diphenylmethylene(3-tert-butyl-5-methyl-cyclopentadienyl) (fluorenyl)titanium dichloride, diphenylmethylene (3-tert-butyl-5-methyl-cyclopentadienyl) (2,7-di-tert-butylfluorenyl)titanium dichloride, diphenylmethylene(3-tert-butyl-5-methyl-cyclopentadienyl) (3,6-di-tert-butylfluorenyl)titanium dichloride, diphenylmethylene(3-tert-butyl-5-methyl-cyclopentadienyl) (octamethyloctahydrodibenzofluorenyl)titanium dichloride, diphenylmethylene(3-tert-butyl-5-methyl-cyclopentadienyl) (fluorenyl)hafnium dichloride, diphenylmethylene (3-tert-butyl-5-methyl-cyclopentadienyl) (2,7-di-tert-butylfluorenyl)hafnium dichloride, diphenylmethylene(3-tert-butyl-5-methyl-cyclopentadienyl) (3,6-di-tert-butylfluorenyl)hafnium dichloride and diphenylmethylene(3-tert-butyl-5-methyl-cyclopentadienyl) (octamethyloctahydrodibenzofluorenyl)hafnium dichloride.

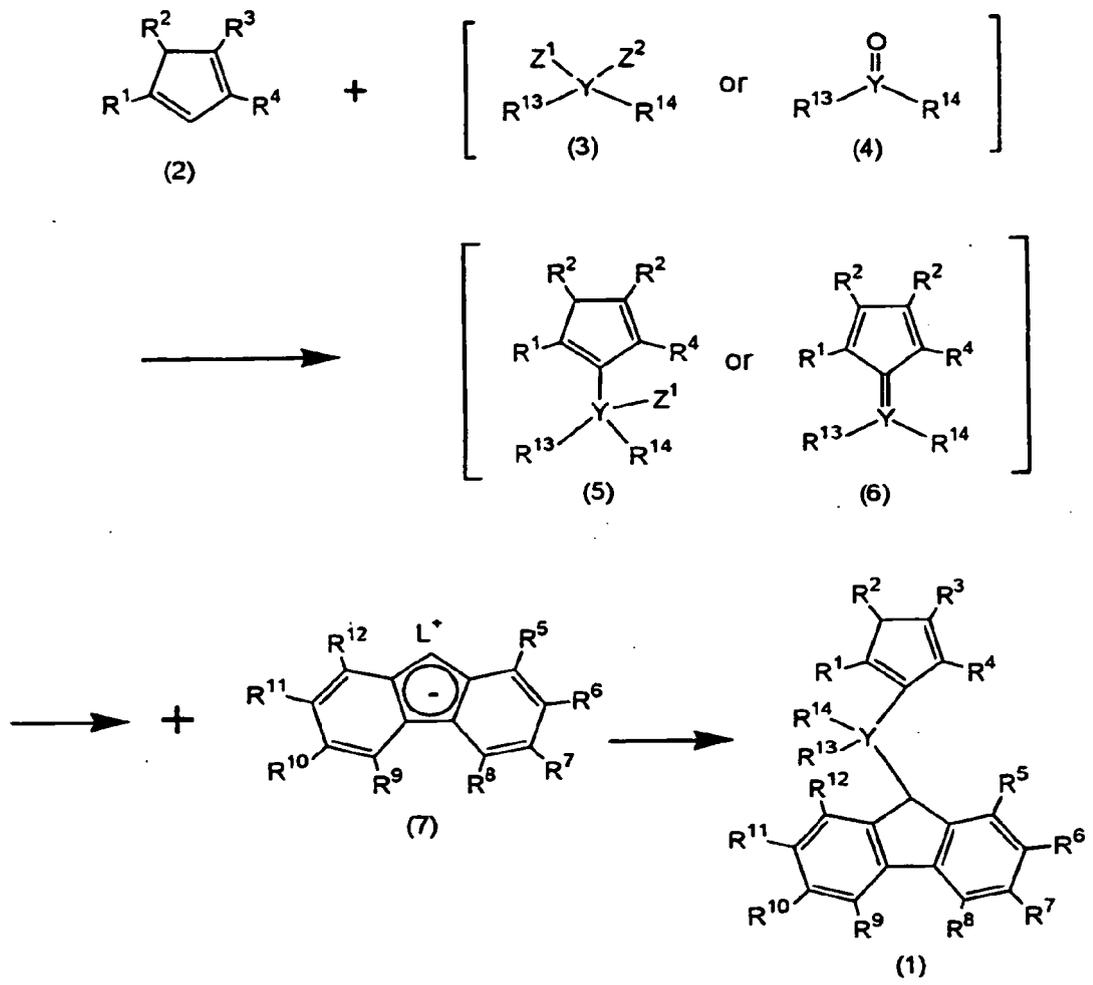
Production process for the transition metal compound

[0142] The transition metal compound, for example the compound of the formula (2a), may be synthesized as described below.

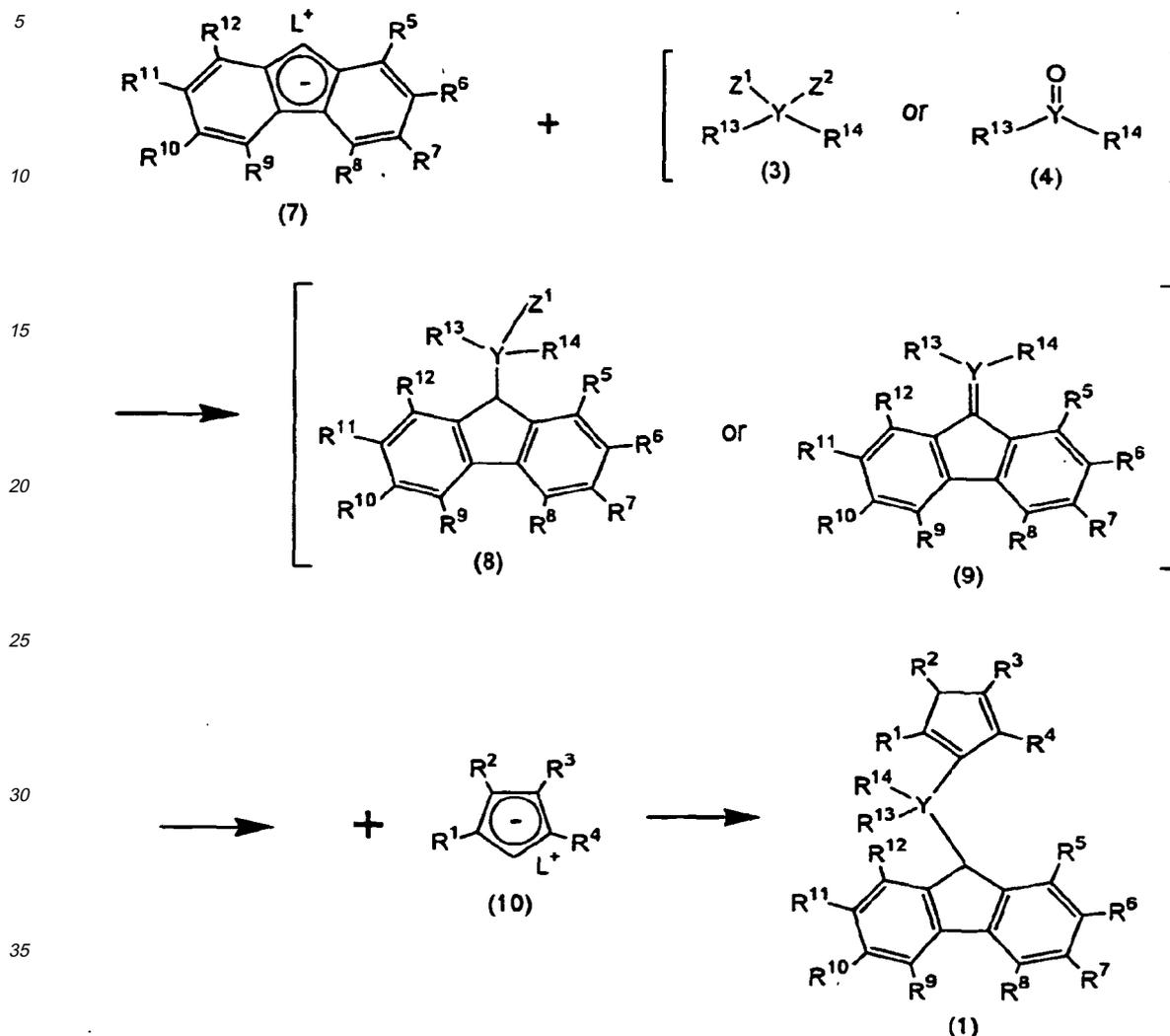
[0143] First, a precursor compound (1) of the compound represented by the formula (2a) is prepared by a series of steps [A] or [B] illustrated below:

[A]

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[B]



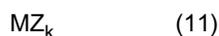
wherein R¹ to R¹⁴ and Y are as defined for the formula (2a); L is an alkali metal; Z¹ and Z², which may be the same or different, are each a halogen or an anionic ligand; and (1), (2) and (5), which are shown with one exemplary form in the formulae, may be each an isomer different only in the positions of the double bonds in the cyclopentadienyl ring, or a mixture of such isomers.

[0144] In the reaction process [A] or [B], the alkali metal used may be lithium, sodium or potassium; the alkali earth metal may be magnesium or calcium; the halogen may be fluorine, chlorine, bromine or iodine; and the anionic ligand may be an alkoxy group such as methoxy, tert-butoxy or phenoxy, a carboxylate group such as acetate or benzoate, or a sulfonate group such as mesylate or tosylate.

[0145] An exemplary process for the preparation of the metallocene compound from the precursor compound (1) will be given below. The precursor compound (1) obtained by the reaction process [A] or [B] is brought into contact with an alkali metal, a hydrogenated alkali metal or an organoalkali metal in an organic solvent at a reaction temperature of -80 to 200°C to form a dialkali metal salt. Examples of the organic solvent used herein include aliphatic hydrocarbons such as pentane, hexane, heptane, cyclohexane and decalin; aromatic hydrocarbons such as benzene, toluene and xylene; ethers such as tetrahydrofuran, diethylether, dioxane and 1,2-dimethoxyethane; and halogenated hydrocarbons such as dichloromethane and chloroform. Exemplary alkali metals for use in the reaction include lithium, sodium and potassium; exemplary alkali metal hydrides include sodium hydride and potassium hydride; and exemplary organoalkali metals include methyllithium, butyllithium and phenyllithium.

[0146] Thereafter, the dialkali metal salt resulting from the above contact is reacted in an organic solvent with a

compound represented by the formula (11) below to give the metallocene compound of the formula (2a):



5 wherein M is a metal selected from Group 4 of the periodic table; Z is a halogen, an anionic ligand or a neutral ligand capable of coordination by a lone pair of electrons, and may be the same or different; and k is an integer of 3 to 6. Preferred compounds having the formula (11) include trivalent or tetravalent titanium fluorides, titanium chlorides, titanium bromides and titanium iodides; tetravalent zirconium fluorides, zirconium chlorides, zirconium bromides and zirconium iodides; tetravalent hafnium fluorides, hafnium chlorides, hafnium bromides and hafnium iodides; and complexes thereof
10 with ethers such as tetrahydrofuran, diethylether, dioxane and 1,2-dimethoxyethane. The organic solvent used herein is as described above. The reaction between the dialkali metal salt and the compound of the formula (11) is preferably an equimolar reaction and is carried out in the organic solvent at a reaction temperature of -80 to 200°C. The resultant metallocene compound may be isolated and purified by, for example, extraction, recrystallization and sublimation. Identification of the transition metal compound of the present invention obtained as above can be made by a proton NMR
15 spectrum, a ¹³C-NMR spectrum, mass spectrometric analysis and elemental analysis.

Preferred embodiment of the transition metal compound in olefin polymerization catalysts

[0147] A preferable embodiment of the transition metal compound for use as an olefin polymerization catalyst will be
20 given below. When the transition metal compound is used to form an olefin polymerization catalyst, catalyst components preferably comprise:

- (A) the transition metal compound,
- (B) at least one compound selected from:

25 (B-1) an organometallic compound,
(B-2) an organoaluminum oxy-compound and
(B-3) a compound capable of forming an ion pair by reacting with the transition metal compound (A), and optionally

30 (C) a particle carrier.

[0148] Each component will be described in detail hereinbelow.

(B-1) Organometallic compound

35 [0149] The organometallic compound (B-1) for use in the present invention is a compound of an organic metal compound selected from Group 1, 2, 12 and 13, for example:

(B-1a) organoaluminum compounds represented by:



wherein R^a and R^b, which may be the same or different, are each a hydrocarbon group of 1 to 15, preferably 1 to 4 carbon atoms, X is a halogen atom, 0 < m ≤ 3, 0 ≤ n < 3, 0 ≤ p < 3, 0 ≤ q < 3 and m+n+p+q=3, such as trimethylaluminum,
45 triethylaluminum, triisobutylaluminum and diisobutylaluminumhydride;

(B-1b) alkyl complex compounds of Group 1 metal and aluminum, represented by:



50 wherein M² is Li, Na or K, and R^a is a hydrocarbon group of 1 to 15, preferably 1 to 4 carbon atoms, such as LiAl(C₂H₅)₄ and LiAl(C₇H₁₅)₄;

(B-1c) dialkyl compounds of Group 2 or 12 metal, represented by:



55 wherein R^a and R^b, which may be the same or different, are each a hydrocarbon group of 1 to 15, preferably 1 to 4 carbon atoms, and M³ is Mg, Zn or Cd.

[0150] Of the above organometallic compounds (B-1), the organoaluminum compounds are preferred. The organometallic compounds (B-1) may be used individually or in combination of two or more kinds.

(B-2) Organoaluminum oxy-compound

[0151] The organoaluminum oxy-compound (B-2) for use in the present invention may be a conventional aluminoxane, or a benzene-insoluble organoaluminum oxy-compound as disclosed in JP-A-H02-78687.

[0152] For example, the conventional aluminoxanes may be prepared by the following methods, and are normally obtained as solution in a hydrocarbon solvent.

(1) An organoaluminum compound, such as trialkylaluminum, is added to a hydrocarbon medium suspension of a compound containing absorbed water or a salt containing water of crystallization (such as magnesium chloride hydrate, copper sulfate hydrate, aluminum sulfate hydrate, nickel sulfate hydrate or cerous chloride hydrate), to react the organoaluminum compound with the absorbed water or water of crystallization.

(2) Water, ice or water vapor is allowed to react directly with an organoaluminum compound, such as trialkylaluminum, in such a medium as benzene, toluene, diethylether or tetrahydrofuran.

(3) An organoaluminum compound, such as trialkylaluminum, is reacted with an organotin oxide, such as dimethyltin oxide or dibutyltin oxide, in such a medium as decane, benzene or toluene.

[0153] The aluminoxane may contain small amounts of organometallic components. After the solvent and unreacted organoaluminum compound are distilled away from the recovered solution of the aluminoxane, the remainder may be redissolved in a solvent or suspended in a poor solvent for the aluminoxane. Examples of the organoaluminum compound used in preparing the aluminoxane include the compounds listed as the organoaluminum compounds (B-1a). Of those compounds, trialkylaluminum and tricycloalkylaluminum are preferred, and trimethylaluminum is particularly preferred.

The organoaluminum compounds may be used individually or in combination of two or more kinds.

[0154] The benzene-insoluble organoaluminum oxy-compound of the present invention desirably contains A1 components that will dissolve in 60°C benzene, in an amount of 10% or less, preferably 5% or less, and particularly preferably 2% or less in terms of Al atom. That is, the organoaluminum oxy-compound is preferably insoluble or hardly soluble in benzene. The organoaluminum oxy-compounds (B-2) may be used individually or in combination of two or more kinds.

(B-3) Compound capable of forming an ion pair by reacting with the transition metal compound

[0155] The compound (B-3) capable of forming an ion pair by reacting with the transition metal compound (A) (hereinafter the "ionizing ionic compound") of the present invention can be selected from, for example, the Lewis acids, ionic compounds, borane compounds and carborane compounds disclosed in JP-A-H01-501950, JP-A-H01-502036, JP-A-H03-179005, JP-A-H03-179006, JP-A-H03-207703, JP-A-H03-207704 and U.S. Patent No. 5321106. Further, heteropoly compounds and isopoly compounds are also employable. These ionizing ionic compounds (B-3) may be used individually or in combination of two or more kinds. When the transition metal compound of the present invention is used in combination with the organoaluminum oxy-compound (B-2), for example methyl aluminoxane, as an auxiliary catalyst component, the resultant olefin polymerization catalyst will exhibit particularly high polymerization activity for olefin compounds.

[0156] In addition to the transition metal compound (A) and at least one compound (B) of the organometallic compound (B-1), the organoaluminum oxy-compound (B-2) and the ionizing ionic compound (B-3), the olefin polymerization catalyst may optionally contain a carrier (C).

(C) Carrier

[0157] The carrier (C) used in the present invention is an inorganic or organic solid compound of granular or fine particle state. Preferred inorganic compounds include porous oxides, inorganic chlorides, clays, clay minerals and ion-exchange layered compounds.

[0158] Suitable porous oxides include SiO_2 , Al_2O_3 , MgO , ZrO_2 , TiO_2 , B_2O_3 , CaO , ZnO , BaO , ThO_2 , and composites and mixtures thereof such as natural or synthetic zeolites, $\text{SiO}_2\text{-MgO}$, $\text{SiO}_2\text{-Al}_2\text{O}_3$, $\text{SiO}_2\text{-TiO}_2$, $\text{SiO}_2\text{-V}_2\text{O}_5$, $\text{SiO}_2\text{-Cr}_2\text{O}_3$ and $\text{SiO}_2\text{-TiO}_2\text{-MgO}$. Of these, porous oxides whose main components are SiO_2 and/or Al_2O_3 are preferable. The porous oxides have various properties depending on the types and how they are produced. The carrier used in the present invention desirably ranges in particle diameter from 5 to 300 μm , preferably from 10 to 200 μm , and in specific surface area from 50 to 1000 m^2/g , preferably 100 to 700 m^2/g , and in pore volume from 0.3 to 3.0 cm^3/g . The carrier may optionally be calcined at 100 to 1000°C, preferably at 150 to 700°C prior to use.

[0159] Suitable inorganic chlorides include MgCl_2 , MgBr_2 , MnCl_2 and MnBr_2 . The inorganic chlorides may be used

directly or after ground by a ball mill or a vibration mill. Alternative prior-to-use treatment is such that the inorganic chlorides are dissolved in a solvent, such as alcohol, and are separated out as fine particles by means of a separating agent.

[0160] The clay for use in the present invention mainly comprises a clay mineral. The ion-exchange layered compound for use in the present invention has a crystal structure in which planes formed by ionic bonds pile parallel one another with weak bonding strength, and contains exchangeable ions. Most clay minerals are the ion-exchange layered compounds. The clays, clay minerals and ion-exchange layered compounds may be natural or synthetic. Examples of the clays, clay minerals and ion-exchange layered compounds include clays, clay minerals and ionic crystalline compounds having a layered crystal structure such as hexagonal closest packing structure, antimony structure, CdCl₂ structure or CdI₂ structure. Exemplary clays and clay minerals include kaolin, bentonite, kibushi clay, potter's clay, allophane, hisingerite, pyrophyllite, mica, montmorillonite, vermiculite, chlorite, palygorskite, kaolinite, nacrite, dickite and halloysite. Exemplary ion-exchange layered compounds include crystalline acid salts of polyvalent metals, such as α -Zr(HAsO₄)₂·H₂O, α -Zr(HPO₄)₂, α -Zr(KPO₄)₂·3H₂O, α -Ti(HPO₄)₂, α -Ti(HAsO₄)₂·H₂O, α -Sn(HPO₄)₂·H₂O, γ -Zr(HPO₄)₂, γ -Ti(HPO₄)₂ and γ -Ti(NH₄PO₄)₂·H₂O. Preferably, the clays and clay minerals of the present invention are chemically treated. The chemical treatment may be, for example, a surface treatment to remove impurities adhering to the surface or a treatment affecting the crystal structure of the clay. Examples of such chemical treatments include acid treatment, alkali treatment, salt treatment and organic substance treatment.

[0161] The ion-exchange layered compound used in the present invention may be enlarged in interlaminar spacing by replacing the exchangeable ions between layers with larger and bulkier ions by means of its ion exchangeability. The bulkier ions play a role as supporting columns in the layered structure, and are generally called pillars. Introduction of different compounds between layers of a layered compound is called intercalation. Guest compounds for the intercalation include cationic inorganic compounds such as TiCl₄ and ZrCl₄, metallic alkoxides such as Ti(OR)₄, Zr(OR)₄, PO(OR)₃ and B(OR)₃ (wherein R is a hydrocarbon group or the like), and metallic hydroxide ions such as [Al₁₃O₄(OH)₂₄]⁷⁺, [Zr₄(OH)₁₄]²⁺ and [Fe₃O(OCOCH₃)₆]⁺. These compounds may be used individually or in combination of two or more kinds. The intercalation of these compounds may be carried out in the presence of polymers obtained by hydrolysis of metallic alkoxides such as Si(OR)₄, Al(OR)₃ and Ge(OR)₄ (wherein R is a hydrocarbon group or the like), or in the presence of colloidal inorganic compounds such as SiO₂. Exemplary pillars include oxides which occur as a result of thermal dehydration after the metallic hydroxide ions have been intercalated between layers. Of the inorganic compounds, the clays and clay minerals, particularly montmorillonite, vermiculite, pectolite, taeniolite and synthetic mica, are preferred.

[0162] Exemplary organic compounds include granular or particulate solids ranging from 5 to 300 μ m in particle diameters. Specific examples include (co)polymers mainly comprising α -olefins of 2 to 14 carbon atoms such as ethylene, propylene, 1-butene and 4-methyl-1-pentene; (co)polymers mainly comprising vinylcyclohexane and styrene; and modified products thereof.

[0163] In addition to the aforementioned transition metal compound (A), at least one compound (B) of the organometallic compound (B-1), the organoaluminum oxy-compound (B-2) and the ionizing ionic compound (B-3), and optional carrier (C), the olefin polymerization catalyst used in the present invention may optionally contain a specific organic compound component (D).

(D) Organic compound component

[0164] The organic compound component (D) used in the present invention is used optionally for the purpose of improving the polymerization activity and obtaining polymers with enhanced properties. Examples of the organic compound include, although not limited thereto, alcohols, phenolic compounds, carboxylic acids, phosphorous compounds and sulfonates.

[0165] In carrying out polymerization, the above components may be used arbitrarily in any addition sequence. Some examples are given below:

- (1) The component (A) alone is fed to a polymerization reactor.
- (2) The components (A) and (B) are fed to a polymerization reactor in arbitrary sequence.
- (3) A catalyst component in which the component (A) is supported on the carrier (C), and the component (B) are fed to a polymerization reactor in arbitrary sequence.
- (4) A catalyst component in which the component (B) is supported on the carrier (C), and the component (A) are fed to a polymerization reactor in arbitrary sequence.
- (5) A catalyst component in which the components (A) and (B) are supported on the carrier (C) is fed to a polymerization reactor.

[0166] In the above methods (2) to (5), the two or more catalyst components may be previously in contact with each other when they are fed to a polymerization reactor. In the method (4) and (5) in which the component (B) is supported

on the carrier, an unsupported component (B) may be added at an arbitrary sequence according to necessity. The supported component (B) and the unsupported component (B) may be the same or different. The solid catalyst component in which the component (A) is supported on the component (C) or in which the components (A) and (B) are supported on the component (C), may be prepolymerized with an olefin. Another catalyst component may be supported on the prepolymerized solid catalyst component.

[0167] In the production process for olefin polymers, one or more olefins are polymerized or copolymerized in the presence of the aforesaid olefin polymerization catalyst to give olefin polymers. The polymerization may be carried out by a liquid-phase polymerization process, such as solution polymerization or suspension polymerization, or a gas-phase polymerization process. The liquid-phase polymerization may be conducted using an inert hydrocarbon solvent. Examples thereof include aliphatic hydrocarbons such as propane, butane, pentane, hexane, heptane, octane, decane, dodecane and kerosine; alicyclic hydrocarbons such as cyclopentane, cyclohexane and methylcyclopentane; aromatic hydrocarbons such as benzene, toluene and xylene; halogenated hydrocarbons such as ethylene chloride, chlorobenzene and dichloromethane; and mixtures thereof. The olefin itself can work as a solvent.

[0168] In carrying out polymerization of olefins in the presence of the olefin polymerization catalyst, the component (A) is used in an amount of 10^{-8} to 10^{-2} mol, preferably 10^{-7} to 10^{-3} mol per liter of the reaction volume. The component (B-1) is used in an amount such that the molar ratio ((B-1)/M) of the component (B-1) to all the transition metal atoms (M) in the component (A) will be 0.01 to 5000, preferably 0.05 to 2000. The component (B-2) is used in an amount such that the molar ratio ((B-2)/M) of the component (B-2) in terms of aluminum atom to all the transition metal atoms (M) in the component (A) will be 10 to 5000, preferably 20 to 2000. The component (B-3) is used in an amount such that the molar ratio ((B-3)/M) of the component (B-3) to the transition metal atoms (M) in the component (A) will be 1 to 10, preferably 1 to 5.

[0169] The component (D) is used in an amount such that:

- the molar ratio ((D)/(B-1)) will be 0.01 to 10, preferably 0.1 to 5 in the case that the component (B) is the component (B-1);
- the molar ratio ((D)/(B-2)) will be 0.01 to 2, preferably 0.005 to 1 in the case that the component (B) is the component (B-2); and
- the molar ratio ((D)/(B-3)) will be 0.01 to 10, preferably 0.1 to 5 in the case that the component (B) is the component (B-3).

[0170] The olefin polymerization using the olefin polymerization catalyst is generally conducted at -50 to $+200^{\circ}\text{C}$, preferably 0 to 170°C . The polymerization pressure may range from atmospheric pressure to 10 MPa (gauge pressure), preferably from atmospheric pressure to 5 MPa (gauge pressure). The polymerization can be carried out batchwise, semi-continuously or continuously, and in two or more stages under different conditions. The molecular weights of resulting olefin polymers may be adjusted by adding hydrogen to the polymerization system, by controlling the polymerization temperature or by changing the amount of the component (B). When hydrogen is added, the addition is suitably conducted at 0.001 to 100 NL based on 1 kg of olefin.

[0171] For the polymerization of the polymers of present invention, at least one monomer is preferably selected from ethylene and α -olefins, in which ethylene or propylene is an essential monomer. Examples of the α -olefins include linear or branched α -olefins of 3 to 20, preferably 3 to 10 carbon atoms, such as propylene, 1-butene, 2-butene, 1-pentene, 3-methyl-1-butene, 1-hexene, 9-methyl-1-pentene, 3-methyl-1-pentene, 1-octene, 1-decene, 1-dodecene, 1-tetradecene, 1-hexadecene, 1-octadecene and 1-eicosene. Suitable monomers further include cycloolefins of 3 to 30, preferably 3 to 20 carbon atoms, such as cyclopentene, cycloheptene, norbornene, 5-methyl-2-norbornene, tetracyclododecene and 2-methyl-1, 4,5, 8-dimethano-1, 2, 3, 4, 4a, 5, 8, 8a-octahydronaphthalene; polar monomers, such as α , β -unsaturated carboxylic acids, including acrylic acid, methacrylic acid, fumaric acid, maleic anhydride, itaconic acid, itaconic anhydride and bicyclo[2.2.1]-5-heptene-2,3-dicarboxylic anhydride, and metal salts thereof with sodium, potassium, lithium, zinc, magnesium and calcium; α , β -unsaturated carboxylates, such as methyl acrylate, ethyl acrylate, n-propyl acrylate, isopropyl acrylate, n-butyl acrylate, isobutyl acrylate, tert-butyl acrylate, 2-ethylhexyl acrylate, methyl methacrylate, ethyl methacrylate, n-propyl methacrylate, isopropyl methacrylate, n-butyl methacrylate and isobutyl methacrylate; vinyl esters, such as vinyl acetate, vinyl propionate, vinyl caproate, vinyl caprate, vinyl laurate, vinyl stearate and vinyl trifluoroacetate; and unsaturated glycidyls, such as glycidyl acrylate, glycidyl methacrylate and monoglycidyl itaconate. Also, the polymerization can be carried out in the presence of vinylcyclohexanes, dienes, polyenes and aromatic vinyl compounds; for example, styrene and mono- or poly-alkyl styrenes, such as o-methylstyrene, m-methylstyrene, p-methylstyrene, o,p-dimethylstyrene, o-ethylstyrene, m-ethylstyrene and p-ethylstyrene; styrene derivatives containing a functional group, such as methoxystyrene, ethoxystyrene, vinylbenzoic acid, vinyl methylbenzoate, vinylbenzyl acetate, hydroxystyrene, o-chlorostyrene, p-chlorostyrene and divinylbenzene; and 3-phenylpropylene, 4-phenylpropylene and α -methylstyrene.

[0172] In the olefin polymerization as described above, at least one monomer is ethylene or propylene. When two or

more monomers are used, either the ethylene or propylene, or both the ethylene and propylene will preferably have an amount of 50 mol% or more relative to all the monomers. The process described above may be favorably used to produce, for example, propylene/butene random copolymers (PBR).

5 EXAMPLES

[0173] The present invention will be described in more detail with reference to the following examples, through the present invention should not be restricted by the examples.

10 **[0174]** Examples and Comparative Examples concerning to laminates prepared by using a propylene/1-butene random copolymer(PBR), polypropylene composition (CC-1) or (CC-2), and polypropylene composition(CC-2) are described hereinafter.

[Methods for measuring physical properties]

15 [1-Butene content]

[0175] The 1-butene content was determined by utilizing ^{13}C -NMR.

[Intrinsic viscosity $[\eta]$]

20 **[0176]** The intrinsic viscosity was measured in decalin at 135°C and indicated by dl/g.

[Molecular weight distribution (Mw/Mn)]

25 **[0177]** The molecular weight distribution (Mw/Mn) was measured using GPC-150C manufactured by Millipore Co., Ltd in the following manner.

[0178] As a separation column, TSK GNH HT was used. The column had a diameter of 27 mm and a length of 600 mm. The column temperature was set to 140°C. For a mobile phase, o-dichlorobenzene (Wako Pure Chemical Industries, Ltd.) and 0.025 wt% of BHT (manufactured by Takeda Chemical Industries, Ltd.) as an antioxidant were used. The mobile phase was moved at a rate of 1.0 ml/min and the specimen concentration was 0.1 wt%. The amount of the injected specimen was 500 μL and a differential refractometer was used as a detector. As standard polystyrenes having a molecular weight of $M_w < 1000$ and $M_w > 4 \times 10^6$, polystyrenes manufactured by Tosoh Co., Ltd were used, and as standard polystyrenes having a molecular weight of $1000 \leq M_w \leq 4 \times 10^6$, polystyrenes manufactured by Pressure Chemical Co., Ltd were used.

35 [B value]

[0179] The B value was determined in such a way that about 200 mg of a copolymer was homogeneously dissolved in 1 ml of hexachlorobutadiene in a 10 mm \varnothing sample tube to prepare a specimen and the ^{13}C -NMR spectrum of the specimen was usually measured under conditions of a measuring temperature of 120°C, a measuring frequency of 25.05 MHz, a spectrum width of 1500 Hz, a filter width of 1500 Hz, a pulse repeating time of 4.2 sec and an integrating time of 2000 to 5000 times, and from the spectrums, P_1 , P_2 and P_{12} (P_1 was an ethylene content fraction, P_2 was a 1-butene content fraction and P_{12} was a proportion of ethylene-1-butene chain in all the molecular chains were calculated.

45 [Triad tacticity]

[0180] The ^{13}C -NMR spectrum was measured using a hexachlorobutadiene solution (on the bases of tetramethylsilane) and the proportion of the area of a peak appeared at 21.0 to 21.9 ppm to all the area (100%) of peaks appeared at 19.5 to 21.9 ppm was determined.

50 [Proportion of irregular bond based on 2,1-insertion]

[0181] The proportion was determined utilizing a ^{13}C -NMR spectrum with the above-described method referring to Polymer, 30, 1350 (1989).

55 [Melting point (TM)]

[0182] About 5 mg of a specimen was charged into an aluminum pan, heated to 200°C at a rate of 10°C/min, and

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maintained for 5 min at 200°C. Thereafter, the temperature was decreased to room temperature at a rate of 20°C/min and then elevated at a rate of 10°C/min. In elevating the temperature, the melting point was determined from an endothermic curve. In the measurement, DSC-7 apparatus (manufactured by Perkin Elmer Co., Ltd) was used.

5 [Crystallinity]

[0183] A press sheet having a thickness of 1.0 mm was molded. After 24 hr from the molding, the crystallinity thereof was determined by X ray diffraction measurement.

10 [Crystallization rate]

[0184] The 1/2 crystallizing time at 45°C was determined using the above DSC apparatus.

[Tensile test]

15

[0185] The tensile strength at yield point in a MD direction, elongation at break and initial modulus of elasticity were measured at a tensile rate of 200 m/min in accordance with JIS K6781.

[Heat-seal strength]

20

[0186] The test was conducted using the laminate films prepared in the following examples as a specimen. The film was laid one on top the other and heat-sealed at a pressure of 2 Kg/cm² for 1 sec by a seal bar having a width of 5 mm at each temperatures, and then allowed to stand.

25

[0187] Subsequently, a 15 mm wide test piece was cut out from the specimen and when the heat-sealed part was peeled at a cross head speed of 200 mm/min, the peeling strength was measured and the resulting value was taken as heat-seal strength.

[Cloudiness (Haze)]

30

[0188] A film was formed in accordance with ASTM D1003 and aged in an air oven set at 80°C for 1 day. Before and after the aging, the cloudiness (haze) was measured.

[Blocking resistance]

35

[0189] The blocking resistance was evaluated in accordance with ASTM D1893. The specimen film for measuring the heat-seal strength (1) was cut out to test pieces having a width of 10 cm and a length of 15 cm. The test pieces were laid one on top the other in such a way that the surfaces on which a polypropylene composition was laminated were faced each other. Then, the test pieces were sandwiched between two plates of glass to prepare a sample. A load of 20 Kg was put on it and the sample was allowed to stand in an air oven at 50°C. After 3 days, the sample was taken out and the peeling strength thereof was measured by a universal testing machine and the resulting value was taken as a blocking value (N/m).

40

[Slip properties]

45

[0190] The coefficient of static friction and the coefficient of dynamic friction were measured in accordance with ASTM D1894.

[0191] The polypropylene and propylene/1-butene copolymer used in the examples and comparative examples of the present invention are described below. In the examples and comparative examples of the present invention, the following polypropylenes prepared by polymerizing with conventional solid titanium catalyst components were used as a polypropylene. Polypropylene-1(PP-1): propylene random copolymer (composition; propylene 96.4 mol%, ethylene 2.1 mol%, 1-butene 1.5 mol%, MFR(230°C); 7.0 g/10 min, DSC melting point; 142°C, Crystallinity; 56%)

50

Polypropylene-2(PP-2): propylene random copolymer (composition; propylene 95.0 mol%, ethylene 3.5 mol%, 1-butene 1.5 mol%, MFR (230°C) ; 1.5 g/10 min, DSC melting point; 140°C, Crystallinity; 52%)

55

Polypropylene-3(PP-3): propylene homopolymer (intrinsic viscosity [η]; 2.9 dl/g, DSC melting point; 164°C, Crystallinity; 62%)

[0192] In the next place, the preparation examples (examples) of the propylene/1-butene copolymers (PBR) are described. The properties of the propylene/1-butene random copolymers (PBR) prepared in the preparation examples (examples) are shown in Table 2.

Reference Example 1 (Synthesis of PBR-1)

[0193] In a 2000 ml polymerization reactor thoroughly purged with nitrogen, 900 ml of dried hexane, 60 g of 1-butene and triisobutylaluminum (1.0 mmol) were charged at room temperature, the inside temperature of the polymerization reactor was elevated to 70°C and pressurized with propylene to 0.7 Mpa. A toluene solution obtained by allowing 0.002 mmol of dimethylmethylene(3-tert-butyl-5-methylcyclopentadienyl) fluorenyl zirconium dichloride to contact with 0.6 mmol in terms of aluminum of methyl aluminoxane (manufactured by Tosoh Fine chemical Co., Ltd) was added to the polymerization reactor. Polymerization was carried out for 30 min while keeping an internal temperature of 70°C and a propylene pressure of 0.7 Mpa and then 20 ml of methanol was added and thereby the polymerization was ceased. After depressurization, a polymer was precipitated from the polymerization solution in 2 L of methanol, and was dried in vacuo at 130°C for 12 hr.

[0194] The polymer was obtained in an amount of 9.2 g. The polymer had a melting point of 80.6°C and an intrinsic viscosity $[\eta]$ of 1.18 dl/g. The physical properties of the resulting polymer were measured.

[0195] The results are shown in Table 2.

Reference Example 2 (Synthesis of PBR-2)

[0196] The polymerization was carried out in the same procedure as Example 1 except that 917 ml of hexane and 50 g of 1-butene were charged and dimethylmethylene(3-tert-butyl-5-methyl cyclopentadienyl)fluorenyl zirconium dichloride was changed to diphenylmethylene (3-tert-butyl-5-methyl cyclopentadienyl) 2,7-di-tert-butylfluorenyl zirconium dichloride.

[0197] The polymer was obtained in an amount of 11.5 g. The polymer had a melting point of 86.3°C and an intrinsic viscosity $[\eta]$ of 2.11 dl/g. The physical properties of the resulting polymer were measured. The results are shown in Table 2.

Example 1 (Synthesis of PBR-3)

[0198] The polymerization was carried out in the same procedure as Reference Example 1 except that 800 ml of hexane and 120 g of 1-butene were charged and the internal temperature of the polymerization reactor was kept at 60°C.

[0199] The polymer was obtained in an amount of 10.8 g. The polymer had an intrinsic viscosity $[\eta]$ of 2.06 dl/g. The physical properties of the resulting polymer were measured. The results are shown in Table 2.

Comparative Example 1 (Synthesis of PBR-C1)

[0200] In a 2 L autoclave thoroughly purged with nitrogen, 830 ml of hexane, 100 g of 1-butene and 1 mmol of triisobutylaluminum were charged and the temperature was elevated to 70°C and the total pressure was set to 0.7 Mpa with feeding propylene. To the autoclave, 1 mmol of triethylaluminum and 0.005 mmol in terms of Ti atom of a titanium catalyst supported on magnesium chloride were added. Polymerization was carried out for 30 min while keeping the total pressure of 0.7 Mpa by continuously feeding propylene. Except for the above, the polymerization and the post treatment were carried out in the same manner as Reference Example 1.

[0201] The polymer was obtained in an amount of 33.7 g. The polymer had a melting point of 110.0°C and an intrinsic viscosity $[\eta]$ of 1.91 dl/g. The physical properties of the resulting polymer were measured.

[0202] The results are shown in Table 2.

Comparative Example 2 (Synthesis of PBR-C2)

[0203] In Comparative Example 2, 900 ml of hexane, 60 g of 1-butene and 1 mmol of triisobutylaluminum were charged and the temperature was elevated to 70°C and the total pressure was set to 0.7 Mpa with feeding propylene. 0.30 mmol of methylaluminoxane and 0.001 mmol in terms of Zr atom of rac-dimethylsilylene-bis{1-(2-methyl-4-phenyl-1-indenyl)} zirconium dichloride were added to the autoclave. Polymerization was carried out for 30 min while keeping the total pressure of 0.7 Mpa by continuously feeding propylene. Except for the above, the polymerization and the post treatment were carried out in the same procedure as Reference Example 1.

[0204] The polymer was obtained in an amount of 39.7 g. The polymer had a melting point of 88.4°C and an intrinsic viscosity $[\eta]$ of 1.60 dl/g.

Comparative Example 3 (Synthesis of PBR-C3)

[0205] The polymerization was carried out in the same manner as Comparative Example 2, except that 842 ml of hexane and 95 g of 1-butene were charged. The polymer was obtained in an amount of 15.1 g. The polymer had a

melting-point of 69.5°C and an intrinsic viscosity $[\eta]$ of 1.95 dl/g. The physical properties of the resulting polymer were measured. The results are shown in Table 2.

[0206] With regard to the polymer of Example 1 and the polymer of Comparative Example 3 which have the almost same melting point, the 1/2 crystallization time at 45°C was determined by DSC.

Table 2

	Reference Ex. 1	Reference Ex. 2	Ex. 1
1-Butene content (mol%)	19.1	16.9	28.0
Intrinsic viscosity $[\eta]$ (dl/g)	1.18	2.11	2.06
Mw/Mn	2.04	2.09	2.15
B value	1.01	1.05	1.04
Triad isotacticity (%)	96	96	95
Proportion of irregular bond based on 2,1-insertion	0.1	0.1	0.2
Melting point (°C)	80.6	86.3	66.5
146 exp(-0.022M)	95.9	100.7	78.9
125 exp(-0.032M)	67.8	72.8	51.0
146 exp(-0.0265M)	88.0	93.3	69.5
1/2 crystallization time (min)			5.2

Table 2 (continued)

	Com. Ex. 1	Com. Ex. 2	Com. Ex. 3
1-Butene content (mol%)	23.1	26.4	34.5
Intrinsic viscosity $[\eta]$ (dl/g)	1.91	1.60	1.95
Mw/Mn	3.40	2.05	2.03
B value	0.92	1.00	1.15
Triad isotacticity (%)	99	99	99
Proportion of irregular bond based on 2,1-insertion	<0.01	0.02	0.1
Melting point (°C)	110.0	88.4	69.5
146 exp(-0.022M)	87.8	81.7	68.3
125 exp(-0.032M)	59.7	53.7	41.4
146 exp(-0.0265M)	79.2	72.5	58.5
1/2 crystallization time (min)			33.1

Reference Example 3

[0207] In an air-knife system cast-molding machine equipped with an extruder having a screw diameter of 40 mm and a T-die having a width of 400 mm, 70 wt% of polypropylene-1 and 30 wt% of the propylene/1-butene random copolymer prepared in Reference Example 1 were fed and a film having a thickness of 50 μm was molded in conditions that the resin temperature was 230°C and the chilling temperature was 30°C. The mechanical properties and the heat-seal properties of the resulting film are shown in Table

Reference Example 4, Example 2 and Comparative Examples 4 to 6

[0208] In each Example, the procedure of Reference Example 3 was repeated except for using the propylene/1-butene

random copolymer as described in Table 3, to prepare a film. The evaluation results of the resulting film are shown in Table 3.

Table 3

	Reference Ex. 3	Reference Ex. 4	Ex. 2	Com. Ex.4	Com. Ex. 5	Com. Ex.6
Resin composition						
PP-1 %	70	70	70	70	70	70
PBR-1 % (Ref. Ex. 1)	30					
PBR-2 % (Ref. Ex. 2)		30				
PBR-3 % (Ex. 1)			30			
PBR-C1 % (Com. Ex. 1)				30		
PBR-C2 % (Com. Ex. 2)					30	
PBR-C3 % (Com. Ex. 3)						30
Tensile test						
Yield stress MPa	14	15	13	15	15	14
Elongation at break %	650	650	650	650	650	650
Initial modulus of elasticity MPa	490	530	430	590	570	490
Haze %	2.0	1.8	1.6	1.8	2.6	2.4
Haze % (80°C x 1 day)	2.1	1.8	1.6	3.9	2.7	2.5
Blocking resistance N/m	0.2	0.2	0.2	0.6	0.2	0.2
Slip properties						
Static	0.63	0.60	0.68	0.82	0.65	0.74
Dynamic	0.51	0.46	0.54	0.74	0.59	0.60

Example 3

[0209] In this Example, a composition of 50 wt% of propylene/1-butene random copolymer (PBR-3) prepared in Example 1 and 50 wt% of polypropylene-2 (PP-2) was palletized with a single-screw extruder of 40 mm ϕ . The pellet was fed to a cast-molding machine equipped with a dice having a width of 300 mm and a sheet having a thickness of 250 μ m was prepared at a resin temperature of 230°C. Further, the resulting sheet was cut out into squares having a size of 9 cm and the square was orientated 5 times in a MD direction using a desk stretching-machine. The shrinkage factor of the resulting orientated film was measured in the following method. The results are shown in Table 4.

[Shrinkage factor]

[0210] A stretched film was slit to prepare a sample having a size of 15 mm x 150 mm (stretching direction). The sample was immersed in a hot water at 90°C for 10 sec and the shrinkage factor was determined from the length shrunk and-the-length before shrinking.

Comparative Examples 7 and 8

[0211] In each Example, the procedure of Example 3 was repeated except for using a propylene/1-butene random copolymer having the composition as described in Table 4, to prepare a stretched film. The evaluation results of the resulting stretched film are shown in Table 4.

Table 4

	Ex. 3	Com. Ex. 7	Com. Ex. 8
Resin composition			
PP-2 %	50	50	50
PBR-3 % (Ex. 1)	50		

(continued)

	Ex. 3	Com. Ex. 7	Com. Ex. 8
PBR-C1 % (Com. Ex. 1)		50	
PBR-C3 % (Com. Ex. 3)			50
Shrinkage Factor (%)	32	25	28

Comparative Example 9

[0212] Using an air knife system two-kind three-layer cast molding machine equipped with an extruder (for core layer) having a screw diameter of 30 mm, an extruder (for both sealant layers) having a screw diameter of 25 mm and a T-die having a width of 200 mm, a sample of an unstretched sheet as shown in Fig. 1 was prepared. The core layer comprises polypropylene-3 (PP-3). Both of the sealant layers comprise 75 wt parts of polypropylene-1 (PP-1), 25 wt parts of PBR-2 and, based on the total amount (100 wt parts) of PP-1 and PBR-2, 0.1 wt parts of an anti-blocking agent. In this sheet, the core layer had a thickness of 600 μm and the sealant layers both have a thickness of 80 μm .

[0213] The resulting unstretched sheet sample was cut into a square having a size of 10 cm, and the sample was stretched in 5 x 8 times using a batch biaxial stretching machine to prepare a biaxially stretched film having a thickness of 22 to 24 μm . The stretching was carried out in conditions such that the preheating time was 2 min, the stretching temperature was 160°C, and the annealing time for the film after stretching was 2 min. The physical properties of the film are shown in Table 5.

Example 4

[0214] The procedure of Comparative Example 9 was repeated except that PBR-3 was used instead of PBR-2 used in both of the sealant layers in Comparative Example 9 to prepare a biaxially stretched film having a thickness of about 22 to 24 μm . The physical properties of the film are shown in Table 5.

Example 5

[0215] The procedure of Example 4 was repeated except that 50 wt parts of polypropylene-1 and 50 wt parts of PBR-3 were used to prepare a biaxially stretched film having a thickness of about 22 to 24 μm . The physical properties of the film are shown in Table 5.

Comparative Example 10

[0216] The procedure of Comparative Example 9 was repeated except that PBR-C1 was used instead of PBR-2 used in both of the sealant layers to prepare a biaxially stretched film having a thickness of about 22 to 24 μm . The physical properties of the film are shown in Table 5.

Comparative Example 11

[0217] The procedure of Comparative Example 9 was repeated except that PBR-C2 was used instead of PBR-2 used in both of the sealant layers to prepare a biaxially stretched film having a thickness of about 22 to 24 μm . The physical properties of the film are shown in Table 5.

Comparative Example 12

[0218] The procedure of Comparative Example 9 was repeated except that PBR-C3 was used instead of PBR-2 used in both of the sealant layers to prepare a biaxially stretched film having a thickness of about 22 to 24 μm . The physical properties of the film are shown in Table 5.

Comparative Example 13

[0219] The procedure of Comparative Example 12 was repeated except that 50 wt parts of polypropylene-1 and 50 wt parts of PBR-C3 were used to prepare a biaxially stretched film having a thickness of about 22 to 24 μm . The physical properties of the film are shown in Table 5.

[0220] In the biaxially stretched films prepare using the propylene/1-butene random copolymer (PBR-2, 3) according

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to the present invention, the temperature at which the heat-seal strength reached 2 (N/15 mm) was not higher than 90°C so that the films obtained had remarkably excellent low temperature heat-sealability as compared with Comparative Example 10. The films had good blocking resistance and excellent balance between low temperature heat-sealability and blocking resistance.

[0221] Furthermore, the propylene/1-butene random copolymer (PBR-2, 3) used in the present invention had a relatively higher crystallization rate as compared with the propylene/1-butene random copolymer (PBR-C2, C3) having the same melting point as PBR-2,3, used in Comparative Examples so that the biaxially stretched films prepared using PBR-2, 3 had excellent hot tack properties and transparency.

Table 5-1

	Comparative Example 9	Example 4	Example 5
Polypropylene-1 (wt part)	75	75	50
PBR-2 (wt part) (Com. Ex. 2)	25		
PBR-3 (wt part) (Ex. 1)		25	50
Cloudiness (Haze) (%)	11.0	13.2	13.9
Cloudiness change with time (%)	13.3	14.3	14.0
Slip properties/ Static friction	0.8	0.8	0.8
Slip properties/ Dynamic friction	0.6	0.6	0.7
Blocking resistance (N/m)	0.14	0.14	0.27
Heat seal strength (N/15 mm)			
65°C		0	0.3
70°C	0	0.3	3.1
80°C	0.1	2.1	3.3
90°C	2.6	3.5	3.2
100°C	3.7	3.7	3.4
110°C	3.6	3.6	
120°C	3.6		
Hot tack properties (mm)			
80°C		300	255
90°C	300	220	100
100°C	210	120	40
110°C	125	60	15
120°C	40	25	15
130°C	20	15	
140°C	15	15	

Table 5-2

	Comparative Example			
	10	11	12	13
Polypropylene-1 (wt part)	75	75	75	50
PBR-C1 (wt part)	25			
PBR-C2 (wt part)		25		

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(continued)

	Comparative Example			
	10	11	12	13
PBR-C3 (wt part)			25	50
Cloudiness (Haze) (%)	13.5	15.4	23.7	25.9
Cloudiness change with time (%)	17.3	17.2	26.6	27.9
Slip properties/ Static friction	0.7	0.8	0.9	0.9
Slip properties/ Dynamic friction	0.6	0.6	0.7	0.7
Blocking resistance (N/m)	0.15	0.13	0.14	0.26
Heat seal strength (N/15 mm)				
65°C			0	0.3
70°C			0.2	2.9
80°C	0	0	2.3	3.5
90°C	0.2	2.3	3.3	3.4
100°C	2.4	3.4	3.3	3.4
110°C	3.3	3.6	3.4	
120°C	3.5	3.6		
130°C	3.8			
Hot tack properties (mm)				
80°C				300
90°C		300	300	270
100°C	300	260	185	115
110°C	200	155	120	60
120°C	150	45	75	35
130°C	70	20	20	20
140°C	20	15	20	

[0222] The examples concerning to the transition metal compound of the formula (2a) and the catalysts using the transition metal compound are described below.

[0223] The structures of the compounds obtained in the following synthesis examples were determined by 270MHz ¹H-NMR (JEOL GSH-270), FD- Mass spectrometry (JEOL SX-102A) and the like.

Example 1c

Synthesis of diphenylmethylene(3-tert-butyl-5-methylcyclopentadienyl) (fluorenyl) zirconium dichloride

(1) Synthesis of 3-tert-butyl-1-methyl-6,6-diphenyl fulvene

[0224] In a 200 ml three-necked flask equipped with a magnetic stirrer chip and three-way cock thoroughly purged with nitrogen, 2.73 g of 3-tert-butyl-1-methyl-cyclopentadiene (20.1 mmol) was dissolved in 30 ml of dehydrated tetrahydrofuran in a nitrogen atmosphere. To the solution, 13.5 ml of n-butyl lithium / hexane solution (1.58M: 21.3 mmol) was gradually added dropwise in an ice bath and stirred at room temperature for 3 days. To the reaction solution, 10.5 ml of hexamethyl phosphoramide (60.4 mmol) was added and stirred at room temperature for 1 hr. To the solution, a solution prepared by dissolving 3.87 g of benzophenone (21.2 mmol) in 40 ml of dehydrated tetrahydrofuran was gradually added dropwise in an ice bath and stirred at room temperature over night. To the resulting reaction mixture, 50 ml of a hydrochloric acid aqueous solution (1N) was gradually added dropwise in an ice bath and stirred at room temperature for some time.

Diethyl ether was added to the mixed solution to separate an organic phase. The organic phase was washed with a saturated sodium bicarbonate aqueous solution, water and saturated brine. The organic phase was dried with anhydrous magnesium sulfate, thereafter the drying agent was filtered off and the solvent was distilled off from the filtrate under reduced pressure to give a dark-red liquid. The liquid was purified with a column chromatography using 300 g of silica gel (developing solvent: n-hexane) and the developing solvent was distilled off under reduced pressure, and thereby the aimed compound was obtained in an amount of 3.28 g (10.9 mmol) as a reddish-orange solid (yield: 54%).

(2) Synthesis of (3-tert-butyl-5-methyl-cyclopentadienyl) (fluorenyl)diphenylmethane

[0225] In a 200 ml three-necked flask equipped with a magnetic stirrer chip and three-way cock thoroughly purged with nitrogen, 1.75 g of fluorene (10.5 mmol) was dissolved in 40 ml of dehydrated diethylether in a nitrogen atmosphere. To the solution, 7.0 ml of an n-butyl lithium/hexane solution (1.58M: 11.1 mmol) was gradually added dropwise in an ice bath and stirred at room temperature over night. The solvent was distilled off under reduced pressure and thereby a reddish orange solid was obtained. In a glove box, to the reddish-orange solid, 3.17 g of 3-tert-butyl-1-methyl-6,6-diphenylfulvene (10.6 mmol) was added and dissolved in 50 ml of dehydrated diethyl ether. The solution was stirred for 120 hr while intermittent refluxing in a 50°C oil bath and stirred at room temperature for 496 hr. To the resulting reaction mixture, 50 ml of a distilled water was gradually added dropwise in an ice bath and diethyl ether was added to the mixed solution to separate an organic phase. The organic phase was washed with distilled waster and saturated brine. The organic phase was dried with anhydrous magnesium sulfate, thereafter the drying agent was filtered off and the solvent was distilled off from the filtrate under reduced pressure to give red oil. The red oil was re-crystallized from ethanol and dried under reduced pressure, and thereby the aimed compound was obtained in an amount of 0.648 g (1.39 mmol) as a pale yellow solid (yield: 13 %).

(3) Synthesis of diphenylmethylene(3-tert-butyl-5-methylcyclopentadienyl)(fluorenyl)zirconium dichloride.

[0226] In a 200 ml three-necked flask equipped with a magnetic stirrer chip and three-way cock thoroughly purged with nitrogen, 0.642 g of (3-tert-butyl-5-methyl-cyclopentadienyl) (fluorenyl) diphenyl methane (1.38 mmol) was dissolved in 40 ml of dehydrated diethylether in a nitrogen atmosphere. To the solution, 1.85 ml of a n-butyl lithium/hexane solution (1.58M: 2.92 mmol) was gradually added dropwise at room temperature. The solution was stirred with refluxing for 6 hr and thereafter stirred at room temperature over night. The solvent was distilled off under reduced pressure to give a reddish-orange solid. In a glove box, 0.325 g of zirconium tetrachloride (1.39 mmol) was added to the solid and cooled in a dry ice /methanol bath. To the reaction mixture, 50 ml of dehydrated diethyl ether sufficiently cooled in a dry ice/ methanol bath was transported through a cannular tube and stirred for 4 days while gradually returning the temperature to room temperature. The reaction mixture was introduced into the glove box and the solvent was distilled off under reduced pressure. The residual product was re-slurried with 50 ml of dehydrated hexane and filtered off using a glass filter filled with diatomaceous earth. The filtrate was concentrated to prepare a solid and the solid was washed with dehydrated diethyl ether and dried under reduced pressure, and thereby the aimed compound was obtained in an amount of 35 mg (0.056 mmol) as a reddish-pink solid.

[0227] Furthermore, the reddish-orange solid remained on the filter was washed with a small amount of dichloromethane and the solvent was distilled off under reduced pressure from the filtrate. The resulting reddish-brown solid was washed with a small amount of diethyl ether and dried under reduced pressure, and thereby the aimed compound was obtained in an amount of 11 mg (0.018 mmol) as a reddish-pink solid (yield: 5%). The identification was carried out by ¹H-NMR spectrum and FD-mass spectrometry spectrum. The measurement results are shown below.

[0228] ¹H-NMR spectrum (CDCl₃, TMS standard): /ppm 1.10(s,9H), 1.90(s,3H), 5.68(d, 1H), 6.19(d, 1H), 6.18-6.31 (m, 1H), 6.87-6.93(m, 1H), 6.98-7.09(m, 2H), 7.20-7.55(m,8H), 7.77-7.81(m, 1H), 7.90-7.95(m,3H), 8.11-8.15(m,2H)
FD-mass spectrometry spectrum: M/z = 626(M⁺)

Example 2c

Synthesis of diphenylmethylene(3-tert-butyl-5-methylcyclopentadienyl) (3,6-di-tert-butyl-fluorenyl) zirconium dichloride

(1) Synthesis of (3-tert-butyl-5-methyl-cyclopentadienyl) (3,6-di-tert-butyl-fluorenyl)diphenylmethane

[0229] In a 200 ml three-necked flask equipped with a magnetic stirrer chip and three-way cock thoroughly purged with nitrogen, 3.01 g of 3, 6-di-tert-butyl-fluorene (10.8 mmol) was dissolved in 80 ml of dehydrated diethyl ether in a nitrogen atmosphere. To the solution, 7.6 ml of a n-butyl lithium/hexane solution (1.56M: 11.9 mmol) was gradually added dropwise in an ice bath and stirred at room temperature over night. To the reaction solution, 50 ml of a solution prepared by dissolving 4.86 g of 3-tert-butyl-1-methyl-6,6-diphenyl fulvene (16.2 mmol) in 50 ml of dehydrated diethyl

ether was added and stirred with refluxing for 13 days. To the reaction mixture, 30 ml of distilled water was gradually added dropwise in an ice bath, and thereafter diethyl ether was added to separate an organic phase. The organic phase was washed with distilled water and saturated brine. The organic phase was dried with anhydrous magnesium sulfate, thereafter the drying agent was filtered off and the solvent was distilled off from the filtrate under reduced pressure to give red solid. The red solid was re-crystallized using ethanol and dried under reduced pressure, and thereby the aimed compound was obtained in an amount of 4.42 g (7.63 mmol) as a pale yellow solid (yield: 71 %).

(2) Synthesis of diphenylmethylene(3-tert-butyl-5-methylcyclopentadienyl)(3,6-di-tert-butyl-fluorenyl)zirconium dichloride

[0230] In a 50 ml Schlenk flask equipped with a magnetic stirrer chip and three-way cock thoroughly purged with nitrogen, 1.42 g of (3-tert-butyl-5-methyl-cyclopentadienyl) (3,6-di-tert-butyl-fluorenyl) diphenyl methane (2.45 mmol) was dissolved in 30 ml of dehydrated diethyl ether in a nitrogen atmosphere. To the solution, 5.0 ml of a n-butyl lithium/hexane solution (1.56M: 7.80 mmol) was gradually added dropwise in an ice bath and thereafter stirred at room temperature for two days. The solvent was distilled off under reduced pressure to give a pale orange solid. The pale orange solid was washed with dehydrated pentane and dried under reduced pressure to prepare a pale orange solid. To the solid, 30 ml of dehydrated diethyl ether was added and sufficiently cooled by a dry ice/methanol batch, and then 0.515 g of zirconium tetrachloride (2.21 mmol) was added. The mixture was stirred for 3 days while gradually returning the temperature to room temperature and thereafter the solvent was distilled off. The reaction mixture was introduced into a glove box and was re-slurried with dehydrated pentane and filtered using a glass filter filled with diatomaceous earth. The filtrate was concentrated to prepare a solid and the solid was washed with a small amount of dehydrated toluene and dried under reduced pressure, and thereby the aimed compound was obtained in an amount of 894 mg (1.21 mmol) as a reddish-pink solid (yield: 49%).

[0231] The identification was carried out by ¹H-NMR spectrum and FD-mass spectrometry spectrum. The measurement results are shown below.

[0232] ¹H-NMR spectrum (CDCl₃, TMS standard): /ppm 1.11(s, 9H), 1.41(s,9H), 1.42(s, 9H), 1.88(s,3H), 5.62(d, 1H), 6.12(d, 1H), 6.17-6.21(m, 1H), 6.95-7.02(m,2H), 7.10-7.45(m,7H), 7.79-7.82(m,2H), 7.91-7.97(m,3H), 8.04-8.07(m,2H)
FD-mass spectrometry spectrum: M/z = 738(M⁺)

Example 3c

Synthesis of diphenylmethylene(3-tert-butyl-5-methylcyclopentadienyl) (2,7-di-tert-butyl-fluorenyl) zirconium dichloride

(1) Synthesis of (3-tert-butyl-5-methyl-cyclopentadienyl) (2,7-di-tert-butyl-fluorenyl)diphenylmethane

[0233] In a 200 ml three-necked flask equipped with a magnetic stirrer chip and three-way cock thoroughly purged with nitrogen, 2.53 g of 2, 7-di-tert-butyl-fluorene (9.10 mmol) was dissolved in 70 ml of dehydrated diethyl ether in a nitrogen atmosphere. To the solution, 6.4 ml of a n-butyl lithium/hexane solution (1.56M: 9.98 mmol) was gradually added dropwise in an ice bath and stirred at room temperature over night. To the reaction solution, a solution prepared by dissolving 3.01 g of 3-tert-butyl-1-methyl-6,6-diphenyl fulvene (10.0 mmol) in 40 ml of dehydrated diethyl ether was added and stirred with refluxing for 7 days. The reaction mixture was added to 100 ml of a hydrochloric acid aqueous solution (1N) and thereafter diethyl ether was added to separate an organic phase. The organic phase was washed with a saturated sodium bicarbonate aqueous solution and saturated brine. The organic phase was dried with anhydrous magnesium sulfate, thereafter the drying agent was filtered off and the solvent was distilled off from the filtrate under reduced pressure to give a reddish-brown liquid. The liquid was purified by a column chromatography using 180 g of silica gel (developing solvent: n-hexane) and the developing solvent was distilled off under reduced pressure. The remainder was re-crystallized using methanol and dried under reduced pressure, and thereby the aimed compound was obtained in an amount of 1.65 g (2.85 mmol) as a pale yellow solid (yield: 31 %).

(2) Synthesis of diphenylmethylene(3-tert-butyl-5-methylcyclopentadienyl)(2,7-di-tert-butyl-fluorenyl)zirconium dichloride

[0234] In a 50 ml Schlenk flask equipped with a magnetic stirrer chip and three-way cock thoroughly purged with nitrogen, 0.502 g of (3-tert-butyl-5-methyl-cyclopentadienyl) (2,7-di-tert-butyl-fluorenyl) diphenyl methane (0.868 mmol) was dissolved in 30 ml of dehydrated diethylether in a nitrogen atmosphere. To the solution, 1.40 ml of a n-butyl lithium/hexane solution (1.56M: 2.18 mmol) was gradually added dropwise in an ice bath and thereafter stirred at room temperature over night. The solvent was distilled off under reduced pressure to give an orange solid. The orange solid was washed with dehydrated pentane and dried under reduced pressure to prepare an orange solid. To the solid, 30 ml of

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dehydrated diethyl ether was added and sufficiently cooled by a dry ice/methanol bath, and then 0.206 g of zirconium tetrachloride (0.882 mmol) was added. The mixture was stirred for 2 days while gradually returning the temperature to room temperature and thereafter the solvent was distilled off under reduced pressure. The reaction mixture was introduced into a glove box and was re-slurried with dehydrated hexane and filtered using a glass filter filled with diatomaceous earth. The filtrate was concentrated to prepare a solid and the solid was washed with a small amount of dehydrated toluene and dried under reduced pressure, and thereby the aimed compound was obtained in an amount of 140 mg (0.189 mmol) as a pink solid (yield: 22%).

[0235] The identification was carried out by ¹H-NMR spectrum and FD-mass spectrometry spectrum. The measurement results are shown below.

[0236] ¹H-NMR spectrum (CDCl₃, TMS standard): δ/ppm 0.99(s,9H), 1.09(s, 9H), 1.12(s,9H), 1.91(s,3H), 5.65(d, 1H), 6.14(d, 1H), 6.23(m, 1H), 7.03(m, 1H), 7.18-7.46(m,6H), 7.54-7.69(m,2H), 7.80-7.83(m, 1H), 7.95-8.02(m,5H)
FD-mass spectrometry spectrum: M/z = 738(M⁺)

Example 4c

Synthesis of di(p-tolyl)methylene(3-tert-butyl-5-methylcyclopentadienyl) (fluorenyl) zirconium dichloride

(1) Synthesis of 3-tert-butyl-1-methyl-6,6-di-(p-tolyl) fulvene

[0237] In a 200 ml three-necked flask equipped with a magnetic stirrer chip and three-way cock thoroughly purged with nitrogen, 1.56 g of powdery potassium hydroxide (27.8 mmol) and 100 ml of dehydrated dimethoxy ethane were added in a nitrogen atmosphere. To the suspension, 2.46 g of 3-tert-butyl-1-methyl-cyclopentadiene (18.0 mmol) was gradually added dropwise at room temperature and stirred under reflux for 2 hr. To the reaction solution, a solution prepared by dissolving 3.99 g of 4, 4'-dimethylbenzophenone (19.0 mmol) in 40 ml of dehydrated dimethoxy ethane was gradually added and stirred under reflux for 3 days. To the reaction mixture, 50 ml of a hydrochloric acid aqueous solution (1N) was gradually added dropwise in an ice bath, and stirred at room temperature for some time. The organic phase was separated by adding diethyl ether and washed with a saturated sodium bicarbonate aqueous solution, water and saturated brine. The organic phase was dried with anhydrous magnesium sulfate, and thereafter the drying agent was filtered off and the solvent was distilled off from the filtrate under reduced pressure to give a dark red liquid. The liquid was purified by a column chromatography using 170 g of silica gel (developing solvent: n-hexane) and the developing solvent was distilled off under reduced pressure, and thereby the aimed compound was obtained in an amount of 2.55 g (7.76 mmol) as a red solid (yield: 43 %).

(2) Synthesis of (3-tert-butyl-5-methyl-cyclopentadienyl) (fluorenyl)di(p-tolyl)methane

[0238] In a 200 ml three-necked flask equipped with a magnetic stirrer chip and three-way cock thoroughly purged with nitrogen, 0.373 g of fluorene (2.25 mmol) was dissolved in 60 ml of dehydrated diethylether in a nitrogen atmosphere. To the reaction solution, 1.6 ml of a n-butyl lithium/hexane solution (1.56M: 2.50 mmol) was gradually added dropwise in an ice bath and thereafter stirred at room temperature over night. To the reaction solution, a solution prepared by dissolving 1.10 g of 3-tert-butyl-1-methyl-6,6- di(p-tolyl)fulvene (3.36 mmol) in 60 ml of dehydrated diethyl ether was added and stirred under reflux for 10 days. To the reaction mixture, 30 ml of distilled water was gradually added dropwise in an ice bath, and thereafter the organic layer was separated by adding diethyl ether and washed with distilled water and saturated brine. The organic phase was dried with anhydrous magnesium sulfate and then the drying agent was filtered off. The solvent was distilled off from the filtrate under reduced pressure to give a red brown liquid. The red brown liquid was purified by a column chromatography using 80 g of silica gel (developing solvent: n-hexane) and the developing solvent was distilled off under reduced pressure. The residue product was re-crystallized using hexane and dried under reduced pressure, and thereby the aimed compound was obtained in an amount of 0.140 g (0.282 mmol) as a pale yellow solid (yield: 13 %).

(3) Synthesis of di (p-tolyl)methylene (3-tert-butyl-5-methylcyclopentadienyl)(fluorenyl)zirconium dichloride

[0239] In a 100 ml Schlenk flask equipped with a magnetic stirrer chip and three-way cock thoroughly purged with nitrogen, 0.496 g of (3-tert-butyl-5-methyl-cyclopentadienyl) (fluorenyl) di(p-tolyl) methane (1.00 mmol) was dissolved in 20 ml of dehydrated diethylether in a nitrogen atmosphere. To the solution, 1.35 ml of a n-butyl lithium/hexane solution (1.58M: 2.13 mmol) was gradually added dropwise in an ice bath, and thereafter stirred at room temperature over night. The reaction solution was sufficiently cooled in a dry ice/ methanol bath and then 0.231 g of zirconium tetrachloride (0.990 mmol) was added. The solution was stirred for 4 days while gradually returning the temperature to room temperature, and thereafter the solvent was distilled off under reduced pressure. The reaction mixture was introduced into a

glove box and re-slurried with dehydrated pentane and then filtered with a glass filter filled with diatomaceous earth. The filtrate was concentrated to prepare a solid, and the solid was washed with a small amount of dehydrated diethyl ether and dried under reduced pressure and thereby the aimed compound was obtained as a reddish-pink solid.

[0240] Furthermore, the pink solid remained on the filter was washed with a small amount of dichloromethane and the solvent was distilled off under reduced pressure from the filtrate. The resulting reddish-pink solid was washed with a small amount of diethyl ether and dried under reduced pressure, and thereby the aimed compound was obtained as a reddish-pink solid. The aimed compound was obtained in a total amount of 222 mg (0.340 mmol) (yield: 34%). The identification was carried out by ¹H-NMR spectrum and FD-mass spectrometry spectrum. The measurement results are shown below.

[0241] ¹H-NMR spectrum (CDCl₃, TMS standard): /ppm 1.09(s, 9H), 1.90(s,3H), 2.32(s,6H), 5.67(d, 1H), 6.17(d, 1H), 6.34-6.37(m, 1H), 6.88-6.93(m, 1H), 6.98-7.24(m, 6H), 7.46-7.53(m,2H), 7.62-7.66(m, 1H), 7.76-7.80(m,3H), 8.10-8.14 (m, 2H)

FD-mass spectrometry spectrum: M/z = 654(M⁺)

Example 5c

Synthesis of di(4-tert-butyl-phenyl)methylene(3-tert-butyl-5-methyl-cyclopentadienyl)(fluorenyl)zirconium dichloride

(1) Synthesis of 3-tert-butyl-1-methyl-6,6-di(4-tert-butyl-phenyl)fulvene

[0242] In a 200 ml three-necked flask equipped with a magnetic stirrer chip and three-way cock thoroughly purged with nitrogen, 1.58 g of powdery potassium hydroxide (28.2 mmol) and 100 ml of dehydrated dimethoxy ethane were added in a nitrogen atmosphere. To the suspension, 2.31 g of 3-tert-butyl-1-methyl-cyclopentadiene (17.0 mmol) was gradually added dropwise at room temperature and stirred under reflux for 1 hr. Thereafter, a solution prepared by dissolving 5.25 g of 4,4'-di-tert-butyl-benzophenone (17.8 mmol) to 40 ml of dehydrated dimethoxyethane was gradually added dropwise and stirred under reflux for 2 days. To the resulting reaction mixture, 50 ml of a hydrochloric acid aqueous solution (1N) was gradually added dropwise in an ice bath and stirred at room temperature for some time. Diethyl ether was added to the mixed solution to separate an organic phase. The organic phase was washed with a saturated sodium bicarbonate aqueous solution, water and saturated brine. The organic phase was dried with anhydrous magnesium sulfate, thereafter the drying agent was filtered off and the solvent was distilled off from the filtrate under reduced pressure to give a reddish-brown solid. The solid was purified with a column chromatography using 240 g of silica gel (developing solvent: n-hexane) and the developing solvent was distilled off under reduced pressure, and thereby the aimed compound was obtained in an amount of 2.10 g (5.09 mmol) as a reddish-orange solid (yield: 30%).

(2) Synthesis of (3-tert-butyl-5-methyl-cyclopentadienyl) (fluorenyl)di(4-tert-butyl-phenyl)methane

[0243] In a 200 ml three-necked flask equipped with a magnetic stirrer chip and three-way cock thoroughly purged with nitrogen, 0.653 g of fluorene (3.93 mmol) was dissolved in 50 ml of dehydrated diethylether in a nitrogen atmosphere. To the solution, 2.7 ml of n-butyl lithium / hexane solution (1.58M: 4.27 mmol) was gradually added dropwise in an ice bath and stirred at room temperature over night. To the solution, a solution prepared by dissolving 2.09 g of 3-tert-butyl-1-methyl-6,6-di(4-tert-butyl-phenyl)fulvene (5.06 mmol) in 100 ml of dehydrated diethyl ether was added and stirred under reflux for 10 days and then stirred at room temperature for 11 days. To the reaction mixture, 30 ml of distilled water was gradually added dropwise in an ice bath, and then diethyl ether was added to separate an organic phase. The organic phase was washed with distilled water and saturated brine. The organic phase was dried with anhydrous magnesium sulfate, thereafter the drying agent was filtered off and the solvent was distilled off from the filtrate under reduced pressure to give a reddish-brown solid. The solid was purified with a column chromatography using 150 g of silica gel (developing solvent: n-hexane) and the developing solvent was distilled off under reduced pressure. The remaining product was re-crystallized using hexane and dried under reduced pressure, and thereby the aimed compound was obtained in an amount of 0.439 g (0.758 mmol) as a pale yellow solid (yield: 19%).

(3) Synthesis of di(4-tert-butylphenyl)methylene(3-tert-butyl-5-methyl-cyclopentadienyl) (fluorenyl) zirconium dichloride

[0244] In a 100 ml Schlenk flask equipped with a magnetic stirrer chip and three-way cock thoroughly purged with nitrogen, 0.450 g of (3-tert-butyl-5-methyl-cyclopentadienyl) (fluorenyl) di (4-tert-butyl-phenyl) methane (0.777 mmol) was dissolved in 10 ml of dehydrated diethylether in a nitrogen atmosphere. To the solution, 1.05 ml of n-butyl lithium / hexane solution (1.58M: 1.66 mmol) was gradually added dropwise in an ice bath and stirred at room temperature over night. The reaction solution was cooled sufficiently in an dry ice/methanol bath and 0.224 g of zirconium tetrachloride (0.961 mmol) was added. The solution was stirred for 2 days while returning the temperature to room temperature.

Thereafter, the solvent was distilled off under reduced pressure. The reaction mixture was introduced into a glove box and re-slurried with dehydrated hexane and filtered off using a glass filter filled with diatomaceous earth. The solvent in the filtrate was distilled off to prepare a solid. The solid was washed with a small amount of dehydrated pentane. The solvent of the washing liquid was distilled off and the remaining product was dried under reduced pressure, and thereby

the aimed compound was obtained in an amount of 216 mg (0.292 mmol) as a reddish-orange solid (yield: 38%).

[0245] The identification was carried out by ¹H-NMR spectrum and FD-mass spectrometry spectrum. The measurement results are shown below.

[0246] ¹H-NMR spectrum (CDCl₃, TMS standard): /ppm 1.07(s,9H), 1.27(s+s,18H), 1.83(s,3H), 5.63(d, 1H), 6.12-6.17 (m,2H), 6.80-6.86(m, 1H), 6.93-7.03(m,2H), 7.20-7.38(m,4H), 7.41-7.48(m,2H), 7.60-7.64(m, 1H), 7.71-7.80(m,3H), 8.06-8.09(m, 2H)

FD-mass spectrometry spectrum: M/z = 738(M⁺)

Example 6c

Synthesis of di(4-chloro-phenyl)methylene(3-tert-butyl-5-methyl-cyclopentadienyl)(fluorenyl)zirconium dichloride

(1) Synthesis of 3-tert-butyl-1-methyl-6,6-di(4-chloro-phenyl)fulvene

[0247] In a 200 ml three-necked flask equipped with a magnetic stirrer chip and three-way cock thoroughly purged with nitrogen, 0.65g of powdery potassium hydroxide (13.0 mmol) and 70 ml of dehydrated dimethoxy ethane were added in a nitrogen atmosphere. To the suspension, 1.24 g of 3-tert-butyl-1-methylcyclopentadiene (9.11 mmol) was added dropwise at room temperature and then 2.40 g of 4,4'-dichloro-benzophenone (9.58 mmol) was added and stirred under reflux for 3 days. To a 30 ml of a hydrochloric acid aqueous solution (1N) set in an ice bath, the reaction mixture was gradually added dropwise and stirred for some time. Diethyl ether was added to the mixed solution to separate an organic phase. The organic phase was washed with a saturated sodium bicarbonate aqueous solution, water and saturated brine. The organic phase was dried with anhydrous magnesium sulfate, thereafter the drying agent was filtered off and the solvent was distilled off from the filtrate under reduced pressure to give a reddish-orange solid. The solid was purified with a column chromatography using 110 g of silica gel (developing solvent: n-hexane) and the developing solvent was distilled off under reduced pressure, and thereby the aimed compound was obtained in an amount of 2.79 g (7.56 mmol) as a red solid (yield: 83%).

(2) Synthesis of (3-tert-butyl-5-methyl-cyclopentadienyl) (fluorenyl)di(4-chloro-phenyl)methane

[0248] In a 200 ml three-necked flask equipped with a magnetic stirrer chip and three-way cock thoroughly purged with nitrogen, 1.42 g of fluorene (8.52 mmol) was dissolved in 60 ml of dehydrated diethyl ether in a nitrogen atmosphere. To the solution, 5.6 ml of n-butyl lithium / hexane solution (1.58M: 8.85 mmol) was gradually added dropwise in an ice bath and stirred at room temperature over night. To the reaction solution, 2.99 g of 3-tert-butyl-1-methyl-6,6-di(4-chloro-phenyl)fulvene (8.08 mmol) was added and stirred under reflux for several days. The reaction mixture was gradually added dropwise to 30 ml of a hydrochloric acid aqueous solution (1N) set in an ice bath, and stirred briefly. Therein, diethyl ether was added to separate an organic phase. The organic phase was washed with a saturated sodium bicarbonate aqueous solution, water and saturated brine. The organic phase was dried with anhydrous magnesium sulfate, thereafter the drying agent was filtered off and the solvent was distilled off from the filtrate under reduced pressure to give a red solid. The solid was purified with a column chromatography using 180 g of silica gel (developing solvent: n-hexane) and the developing solvent was distilled off under reduced pressure. Thereafter, the remaining product was recrystallized using hexane and dried under reduced pressure, and thereby the aimed compound was obtained in an amount of 1.69 g (3.16 mmol) as a pale yellow solid (yield: 39%).

(3) Synthesis of di(4-chloro-phenyl)methylene(3-tert-butyl-5-methyl-cyclopentadienyl)(fluorenyl)zirconium dichloride

[0249] In a 30 ml Schlenk flask equipped with a magnetic stirrer chip and three-way cock thoroughly purged with nitrogen, 1.12 g of (3-tert-butyl-5-methyl-cyclopentadienyl)(fluorenyl) di(4-chloro-phenyl) methane (2.09 mmol) was dissolved in 20 ml of dehydrated diethylether in a nitrogen atmosphere. To the solution, 2.7 ml of n-butyl lithium / hexane solution (1.58M: 4.27 mmol) was gradually added dropwise in an ice bath and stirred at room temperature over night. The solvent was distilled off under reduced pressure to prepare a red solid. The solid was washed with dehydrated hexane and dried under reduced pressure to prepare a reddish-orange solid. To the solid, 20 ml of dehydrated diethyl ether was added and the reaction solution was cooled sufficiently in a dry ice/methanol bath and 0.306 g of zirconium tetrachloride (1.31 mmol) was added. The solution was stirred for 3 days while gradually returning the temperature to room temperature. Thereafter, the solvent was distilled off under reduced pressure. The reaction mixture was introduced

into a glove box and re-slurried with dehydrated hexane and filtered off using a glass filter filled with diatomaceous earth. The filtrate was concentrated to prepare a solid. The solid was separated with centrifugal separator and washed with a small amount of dehydrated diethyl ether, and thereby the aimed compound was obtained in an amount of 33.9 mg (0.049 mmol) as a reddish-orange solid (yield: 4%).

[0250] The identification was carried out by ¹H-NMR spectrum and FD-mass spectrometry spectrum. The measurement results are shown below.

[0251] ¹H-NMR spectrum (CDCl₃, TMS standard): /ppm 1.10(s,9H), 1.92 (s,3H), 5.62(d, 1H), 6.20(d, 1H), 6.33-6.36 (s+s, 1H), 6.95-7.08(m,3H), 7.28-7.46(m,3H), 7.50-7.56(m,2H), 7.68-7.72(m, 1H), 7.83-7.88(m,3H), 8.13-8.18(m,2H)
FD-mass spectrometry spectrum: M/z = 699(M⁺)

Example 7c

Synthesis of di(3-trifluoromethyl-phenyl)methylene(3-tert-butyl-5-methyl-cyclopentadienyl)(fluorenyl)zirconium dichloride

(1) Synthesis of 3-tert-butyl-1-methyl-6,6-di(3-trifluoromethyl-phenyl)fulvene

[0252] In a 200 ml three-necked flask equipped with a magnetic stirrer chip and three-way cock thoroughly purged with nitrogen, 40 ml of dehydrated tetrahydrofuran and 1.41 g of 3-tert-butyl-1-methyl-cyclopentadiene (10.4 mmol) were added in a nitrogen atmosphere. To the solution, 7.0 ml of n-butyl lithium/hexane solution (1.58M: 11.1 mmol) was gradually added dropwise in an ice bath and stirred at room temperature for 2 days. To the reaction solution, 5.4 ml of hexamethyl phosphoramidate dried with molecular sieves 4A was added dropwise in an ice bath, and stirred at room temperature for 1hr. Further, to the solution, 3.49 g of 3,3'-di-trifluoromethyl-benzophenone (11.0 mmol) was added and stirred at room temperature for 3 days. To a 30 ml of a hydrochloric acid aqueous solution (1N) set in an ice bath, the reaction mixture was gradually added dropwise and stirred at room temperature for some time. Diethyl ether was added to the mixed solution to separate an organic phase. The organic phase was washed with a saturated sodium bicarbonate aqueous solution, water and saturated brine. The organic phase was dried with anhydrous magnesium sulfate, thereafter the drying agent was filtered off and the solvent was distilled off from the filtrate under reduced pressure to give a dark red solid. The solid was purified with a column chromatography using 140 g of silica gel (developing solvent: n-hexane) and the developing solvent was distilled off under reduced pressure, and thereby the aimed compound was obtained in an amount of 3.88 g (8.89 mmol) as a red solid (yield: 86%).

(2) Synthesis of (3-tert-butyl-5-methyl-cyclopentadienyl) (fluorenyl)di(3-trifluoromethyl-phenyl)methane

[0253] In a 200 ml three-necked flask equipped with a magnetic stirrer chip and three-way cock thoroughly purged with nitrogen, 1.44 g of fluorene (8.69 mmol) was dissolved in 60 ml of dehydrated diethylether in a nitrogen atmosphere. To the solution, 5.8 ml of n-butyl lithium/hexane solution (1.58M: 9.16 mmol) was gradually added dropwise in an ice bath and stirred at room temperature over night. To the reaction solution, 4.15 g of 3-tert-butyl-1-methyl-6,6-di(3-trifluoromethyl-phenyl)fulvene (9.50 mmol) was added and stirred under reflux for several days. The reaction mixture was gradually added dropwise to 30 ml of a hydrochloric acid aqueous solution set (1N) in an ice bath, and stirred at room temperature briefly. Therein, diethyl ether was added to separate an organic phase. The organic phase was washed with distilled water and saturated brine. The organic phase was dried with anhydrous magnesium sulfate, thereafter the drying agent was filtered off and the solvent was distilled off from the filtrate under reduced pressure to give a dark red solid. The solid was purified with a column chromatography using 220 g of silica gel (developing solvent: n-hexane) and the developing solvent was distilled off under reduced pressure. Thereafter, the remaining product was re-crystallized using hexane and dried under reduced pressure, and thereby the aimed compound was obtained in an amount of 1.69 g (2.72 mmol) as a white solid (yield: 31%).

(3) Synthesis of di(3-trifluoromethyl-phenyl)methylene (3-tert-butyl-5-methyl-cyclopentadienyl)(fluorenyl) zirconium dichloride

[0254] In a 30 ml Schlenk flask equipped with a magnetic stirrer chip and three-way cock thoroughly purged with nitrogen, 0.622 g of (3-tert-butyl-5-methyl-cyclopentadienyl)(fluorenyl)di(3-trifluoromethyl-phenyl) methane (1.03 mmol) was dissolved in 20 ml of dehydrated diethyl ether in a nitrogen atmosphere. To the solution, 1.4 ml of n-butyl lithium / hexane solution (1.58M: 2.21 mmol) was gradually added dropwise in an ice bath and stirred at room temperature over night. The reaction solution was sufficiently cooled by an ice bath and 0.208 g of zirconium tetrachloride (0.893 mmol) was added. The solution was stirred for 3 days while gradually returning the temperature to room temperature. Thereafter, the solvent was distilled off under reduced pressure. The reaction mixture was introduced into a glove box and re-slurried

with dehydrated hexane and filtered off using a glass filter filled with diatomaceous earth. The filtrate was concentrated to prepare a solid. The solid was separated with centrifugal separator, washed with a small amount of dehydrated diethyl ether and dried under reduced pressure, and thereby the aimed compound was obtained in an amount of 97.2 mg (0.127 mmol) as a reddish-pink solid (yield: 14%).

[0255] The identification was carried out by ¹H-NMR spectrum and FD-mass spectrometry spectrum. The measurement results are shown below.

[0256] ¹H-NMR spectrum (CDCl₃, TMS standard): /ppm 1.10-1.12(s+s,9H), 1.90 (s,3H), 5.62 (d, 1H), 6.17-6.25(m, 2H), 6.84-6.87 (m, 1H), 6.95-7.09 (m, 2H), 7.42-7.60 (m, 6H), 7.99-8.02 (m, 1H), 8.14-8.20 (m, 5H),
FD-mass spectrometry spectrum: M/z = 762 (M⁺)

Example 8c -Preparation of supported catalyst-

[0257] In a 100 ml three-necked flask thoroughly purged with nitrogen, a stirring rod was mounted, and 1.0 g of silica supported methyl aluminoxane (Al=7.04 mmol/g) was added. Therein, 10 ml of dehydrated toluene was added at room temperature and then 20 ml of a toluene solution of 28.1 μmol of diphenylmethylene(3-tert-butyl-5-methylcyclopentadienyl) (fluorenyl) zirconium dichloride synthesized in Example 1c as a transition metal compound was added with stirring and stirred for 1 hr. The resulting slurry was filtered with a filter, and a powder present on the filter was washed with 10 ml of dehydrated toluene once and then washed with 10 ml of dehydrated hexane three times. The powder obtained after washing was dried under reduced pressure for 1.5 hr and 0.70 g of the powder was obtained. The powder was mixed with 6.40 g of mineral oil to prepare a 9.9 wt% slurry.

INDUSTRIAL APPLICABILITY

[0258] The sheets and films prepared by the polypropylene compositions (CC-2) containing the propylene/1-butene random copolymer and the propylene/1-butene random copolymer according to the present invention have excellent balance of transparency, flexibility and heat-seal properties. Further, the stretched films therefrom have excellent shrinking properties. Therefore, they are suitable for use as sheets or films for packaging food and the like.

[0259] The sheets and films prepared by the polypropylene compositions (CC-2) containing the propylene/1-butene random copolymer and the propylene/1-butene random copolymer according to the present invention have excellent transparency, flexibility, blocking resistance and heat-seal properties. Particularly, they can be heat-sealed even at low temperatures so that they can be heat-sealed in a wide temperature range, and further have excellent heat-seal strength. Additionally even after long-term storage, the heat-seal temperature thereof is not changed with time and the stable heat-sealability is secured. The stretched films obtainable by stretching the above sheets or films have excellent heat-seal properties, blocking properties and shrinking properties.

[0260] The sheets, films and stretched films according to the present invention, further, have excellent transparency, scratching resistance and blocking resistance and can perform high-speed packaging. Therefore, they are suitably used for food packaging, packed wrapping, fiber packaging and other uses.

[0261] The transition metal compound having ligand such that a cyclopentadienyl group having substituent groups at two positions not adjacent each other and a fluorenyl group are bridged with a carbon atom substituted with an aryl group are useful as an olefin polymerization catalyst component.

[0262] The use of the olefin polymerization catalyst containing the transition metal compound can give a process for producing an olefin copolymer having a high molecular weight.

Claims

1. A propylene/1-butene random copolymer (PBR) **characterized by** containing

- (1) 60 to 90 mol% of units derived from propylene and 10 to 40 mol% of units derived from 1-butene, and having
- (2) a triad isotacticity, as determined from a ¹³C-NMR spectrum, of not less than 85% and not more than 97.5%,
- (3) a molecular weight distribution (Mw/Mn), as determined by gel permeation chromatography (GPC), of from 1 to 3,
- (4) an intrinsic viscosity, as measured in decalin at 135°C, of from 0.1 to 12 dl/g,
- (5) a melting point (T_m), as measured on a differential scanning calorimeter, of from 40 to 75 °C,
- (6) a crystallisation rate (½ crystallisation time) at 45°C of 10 minutes or less, and satisfying
- (7) the following relation

$$146 \exp(-0.022M) \geq T_m \geq 125 \exp(-0.032M)$$

5 wherein T_m represents a melting point and M (mol%) represents a content of 1-butene constituent units.

2. A polypropylene composition comprising:

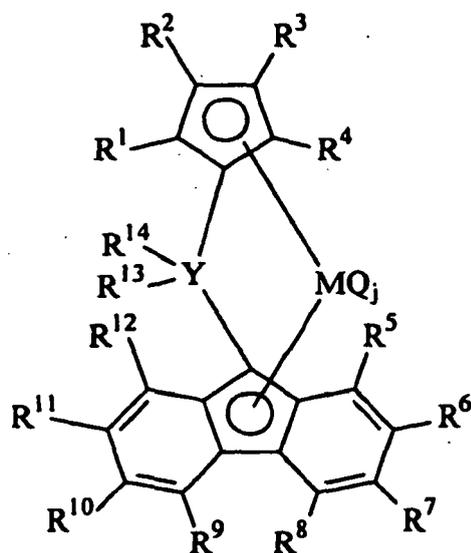
10 5 to 95 wt% of polypropylene (PP-A) and
95 to 5 wt% of a propylene/1-butene random copolymer (PBR) as defined in claim 1.

3. A sheet or film comprising a polypropylene composition as claimed in claim 2.

15 4. A stretched film obtainable by stretching a sheet or film as claimed in claim 3 in at least one direction.

5. A propylene/1-butene copolymer according to claim 1 obtainable by polymerizing propylene and 1-butene in the presence of an olefin polymerization catalyst comprising:

20 a transition metal compound (1a) represented by the following formula (1a)



(1a)

45 in which R^3 is selected from a hydrocarbon group and a silicon-containing group; R^1 , R^2 and R^4 are identical or different and are selected from hydrogen, a hydrocarbon group and a silicon-containing group, R^5 , R^6 , R^7 , R^8 , R^9 , R^{10} , R^{11} , R^{12} , R^{13} and R^{14} are identical or different and are selected from hydrogen, a hydrocarbon group and a silicon-containing group; or adjacent substituent groups R^5 to R^{12} may be linked to each other to form a ring; R^{13} and R^{14} may be the same or different and may be linked to form a ring; M is a Group 4 transition metal; Y is a carbon atom; each Q is identical or different and is selected from halogen, a hydrocarbon group, an anion ligand or a neutral ligand capable of coordination with a lone pair of electrons, and j is an integer of 1 to 4,
50 an organoaluminum oxy-compound (1b) and/or
a compound (2b) capable of forming an ion pair by reacting the transition metal compound (1a) and optionally an organoaluminum compound (c).

6. A polypropylene composite film comprising:

55 (I) a crystalline polypropylene layer and
(II) a layer of a polypropylene composition (II) laminated on at least one surface of the layer (I), wherein the polypropylene composition (CC-2) comprises:

0 to 95 % by weight of a crystalline polypropylene (PP-A) and
5 to 100% by weight of a propylene/1-butene random copolymer (PBR) as defined in claim 1.

7. A stretched film obtainable by stretching the composite film as claimed in claim 6 in at least one direction.

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Patentansprüche

1. Statistisches Propylen/1-Buten-Copolymer (PBR), **dadurch gekennzeichnet, dass es**

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(1) 60 bis 90 mol-% an Einheiten, die von Propylen stammen und 10 bis 40 mol-% von Einheiten, die von 1-Buten stammen, enthält und

(2) eine Triaden-Isotaktizität von nicht weniger als 85% und nicht mehr 97,5%, wie sie aus einem ¹³C-NMR-Spektrum bestimmt wird,

15

(3) eine Molekulargewichtsverteilung (Mw/Mn) von 1 bis 3, wie sie mittels Gelpermeationschromatographie (GPC) bestimmt wird,

(4) eine intrinsische Viskosität von 0,1 bis 12 dl/g, wie sie in Decalin bei 135°C gemessen wird,

(5) einen Schmelzpunkt (T_m) von 40 bis 75°C, wie er an einem dynamischen Differenz-Kalorimeter gemessen wird,

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(6) eine Kristallisationsgeschwindigkeit (1/2 Kristallisationszeit) bei 45°C von 10 Minuten oder weniger aufweist, und

(7) die folgende Relation erfüllt:

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$$146 \exp (-0,022 M) \geq T_m \geq 125 \exp (-0,032 M),$$

wobei T_m einen Schmelzpunkt darstellt und M (mol-%) einen Gehalt an beteiligten 1-Buten-Einheiten darstellt.

2. Polypropylen-zusammensetzung umfassend:

30

5 bis 95 Gew.-% Polypropylen (PP-A) und

95 bis 5 Gew.-% eines statistischen Propylen/1-Buten-Copolymers (PBR), wie es in Anspruch 1 definiert ist.

3. Folie oder Film, die/der eine Polypropylen-Zusammensetzung umfasst, wie sie in Anspruch 2 beansprucht wird.

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4. Gestreckter Film, der durch Strecken einer Folie oder eines Film, wie in Anspruch 3 beansprucht, in mindestens eine Richtung erhältlich ist.

5. Propylen/1-Buten-Copolymer gemäß Anspruch 1, das durch Polymerisation von Propylen und 1-Buten in Gegenwart eines Olefin-Polymerisationskatalysators erhältlich ist, umfassend:

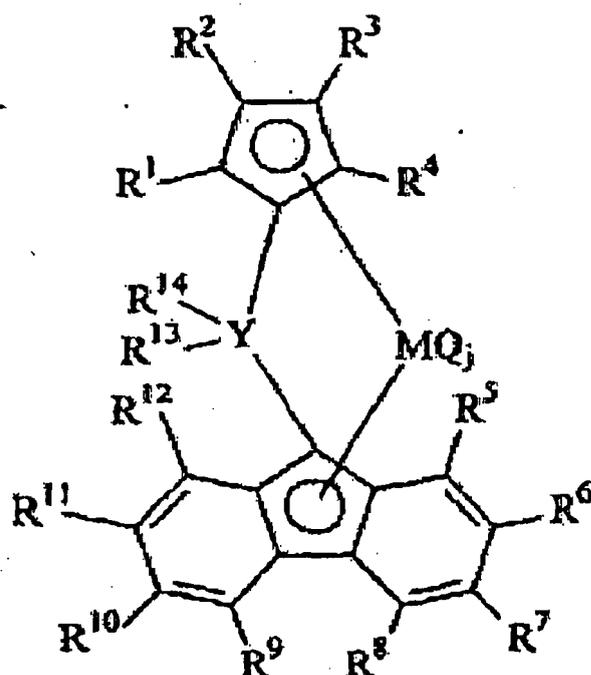
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eine Übergangsmetallverbindung (1a), die durch die folgende Formel (1a) dargestellt ist,

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in der R^3 ausgewählt ist aus einer Kohlenwasserstoffgruppe und einer Silizium enthaltenden Gruppe; R^1 , R^2 and R^4 gleich oder verschieden voneinander sind und ausgewählt sind aus Wasserstoff, einer Kohlenwasserstoffgruppe und einer Silizium enthaltenden Gruppe; R^5 , R^6 , R^7 , R^8 , R^9 , R^{10} , R^{11} , R^{12} , R^{13} und R^{14} gleich oder verschieden voneinander sind und ausgewählt sind aus Wasserstoff, einer Kohlenwasserstoffgruppe und einer Silizium enthaltenden Gruppe; oder benachbarte Substituentengruppen R^5 bis R^{12} miteinander verbunden sein können, um einen Ring zu bilden; R^{13} und R^{14} gleich oder verschieden voneinander sein können und verbunden sein können, um einen Ring zu bilden; M ein Übergangsmetall der Gruppe 4 ist; Y ein Kohlenstoffatom ist; alle Q gleich oder verschieden voneinander sind und ausgewählt sind aus Halogen, einer Kohlenwasserstoffgruppe, einem anionischen Liganden oder einem neutralen Liganden, der in der Lage ist, mit einem nichtbindenden Elektronenpaar eine Koordinationsbindung auszubilden, und j eine ganze Zahl von 1 bis 4 ist, eine Organoaluminium-oxy-Verbindung (1b) und/oder eine Verbindung (2b), die in der Lage ist, ein Ionenpaar durch Reaktion mit der Übergangsmetallverbindung (1a) zu bilden, und gegebenenfalls eine Organoaluminium-Verbindung (c).

6. Polypropylen-Verbundfolie, umfassend:

(I) eine kristalline Polypropylen-Schicht und
 (II) eine Schicht einer Polypropylen-Zusammensetzung (II), die auf mindestens eine Oberfläche der Schicht (I) laminiert ist, wobei die Polypropylen-Zusammensetzung (CC-2) umfasst:

0 bis 95 Gew.-% eines kristallinen Polypropylens (PP-A) und
 5 bis 100 Gew.-% eines statistischen Propylen/1-Buten-Copolymers (PBR), wie es in Anspruch 1 definiert ist.

7. Gestreckter Film, der durch Strecken der Verbundfolie, wie sie in Anspruch 6 beansprucht wird, in mindestens eine Richtung erhältlich ist.

Revendications

1. Copolymère statistique de propylène et de 1-butène (PBR), caractérisé en ce qu'il contient :

1) de 60 à 90 % en moles de motifs dérivés du propylène et de 10 à 40 % en moles de motifs dérivés du 1-butène,

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en ce qu'il présente :

2) un degré d'isotacticité de triade, déterminé à partir de son spectre de RMN de ^{13}C , valant au moins 85 % et au plus 97,5 %,

3) un indice de distribution des masses moléculaires M_w/M_n , déterminé par chromatographie par perméation de gel (GPC), valant de 1 à 3,

4) une viscosité intrinsèque, mesurée dans de la décane à 135°C , de 0,1 à 12 dL/g,

5) un point de fusion T_f , mesuré à l'aide d'un appareil d'analyse enthalpique différentielle, de 40 à 75°C ,

6) et une vitesse de cristallisation indiquée par un temps de demi-cristallisation à 45°C inférieur ou égal à 10 minutes,

et en ce qu'il obéit :

7) à la relation suivante :

$$146 \exp(-0,022 M) \geq T_f \geq 125 \exp(-0,032 M)$$

dans laquelle T_f représente le point de fusion et M représente la proportion, exprimée en pourcentage en moles, des motifs constitutifs dérivés du 1-butène.

2. Composition de polypropylène, comprenant :

- de 5 à 95 % en poids d'un polypropylène (PP-A),

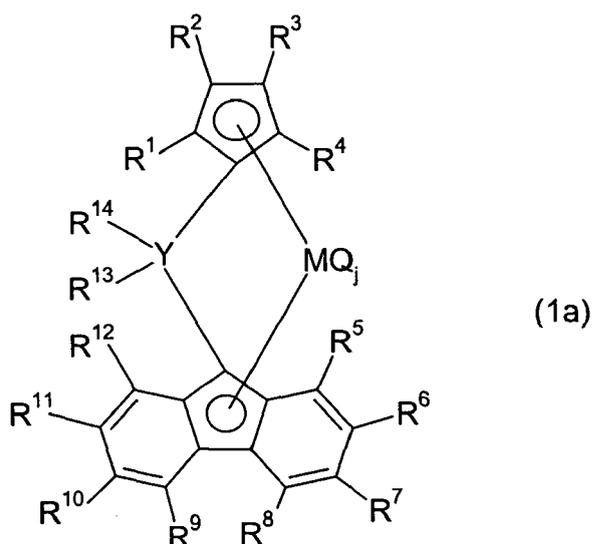
- et de 95 à 5 % en poids d'un copolymère statistique de propylène et de 1-butène (PBR), conforme à la revendication 1.

3. Feuille ou film comprenant une composition de polypropylène conforme à la revendication 2.

4. Film étiré, accessible par étirement, dans au moins une direction, d'une feuille ou d'un film conforme à la revendication 3.

5. Copolymère de propylène et de 1-butène, conforme à la revendication 1, accessible par polymérisation de propylène et de 1-butène en présence d'un catalyseur de polymérisation d'oléfine comprenant :

- un composé (1a) de métal de transition, représenté par la formule suivante :



dans laquelle

- R^3 représente une entité choisie parmi les groupes hydrocarbonés et les groupes contenant du silicium,

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- R¹, R² et R⁴ représentent des entités identiques ou différentes qui sont choisies chacune parmi un atome d'hydrogène, les groupes hydrocarbonés et les groupes contenant du silicium,

- R⁵, R⁶, R⁷, R⁸, R⁹, R¹⁰, R¹¹, R¹², R¹³ et R¹⁴ représentent des entités identiques ou différentes qui sont choisies chacune parmi un atome d'hydrogène, les groupes hydrocarbonés et les groupes contenant du silicium, étant entendu que des groupes substituants adjacents représentés par les symboles R⁵ à R¹² peuvent être raccordés l'un à l'autre et former ainsi un cycle, et que les entités représentées par les symboles R¹³ et R¹⁴ peuvent être identiques ou différentes et peuvent être raccordées et former ainsi un cycle,

- M représente un atome d'un métal de transition du Groupe 4,

- Y représente un atome de carbone,

- les symboles Q représentent des entités identiques ou différentes qui sont choisies chacune parmi les atomes d'halogène, les groupes hydrocarbonés, les ligands anioniques et les ligands neutres capables d'établir une liaison de coordination grâce à une paire d'électrons libres,

- et l'indice j est un nombre entier qui vaut de 1 à 4,

- et un composé de type organo-aluminium-oxy (1b),

- et/ou un composé (2b) capable de former une paire d'ions par réaction avec le composé (1a) de métal de transition,

- et en option, un composé de type organo-aluminium (c).

6. Film composite à base de polypropylène, comprenant :

I) une couche de polypropylène cristallin,

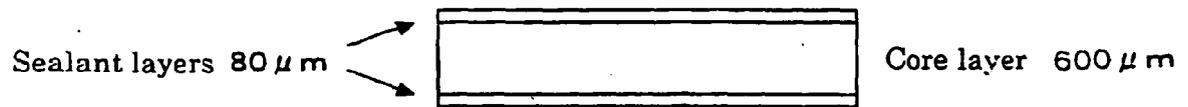
II) et une couche de composition de polypropylène (II), stratifiée sur au moins une face de la couche (I), laquelle composition de polypropylène (CC-2) comprend :

- de 0 à 95 % en poids d'un polypropylène cristallin (PP-A),

- et de 5 à 100 % en poids d'un copolymère statistique de propylène et de 1-butène (PBR), conforme à la revendication 1.

7. Film étiré, accessible par étirement, dans au moins une direction, d'un film composite conforme à la revendication 6.

Fig. 1



REFERENCES CITED IN THE DESCRIPTION

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