

Description

PROCESS FOR PRODUCTION OF SYNDIOTACTIC α -OLEFIN POLYMER

5 Technical Field

[0001]

The present invention relates to a process for producing a syndiotactic α -olefin polymer using a metallocene catalyst comprising a transition metal compound that has a specific
10 structure.

Background Art

[0002]

As a catalyst for the polymerization of α -olefins having
15 3 to 10 carbon atoms to industrially produce olefin polymers, Ziegler-Natta catalysts are known. The Ziegler-Natta catalysts are in worldwide use particularly as a catalyst for the polymerization of C₃, propylene, to produce polypropylene. The Ziegler-Natta catalysts can produce polypropylene having
20 high molecular weight with high activity, and moreover can control the sequences of propylene to high degree, consequently providing polypropylene having high stereoregularity. Accordingly, isotactic polypropylene having high crystallinity and high melting point is obtained. On the other

hand, the Ziegler-Natta catalysts have problems: the presence of plural kinds of active sites in the catalysts by-produces atactic polypropylene, which has irregular propylene sequence, together with the isotactic polypropylene; and in
5 copolymerization of ethylene and an α -olefin having 3 to 10 carbon atoms, the resultant copolymers contain the α -olefin in their polymer chains in a nonuniform proportion, consequently having a wide composition distribution.

[0003]

10 Since the discovery in 1980 by W.Kaminsky et al. of metallocene catalysts, the metallocene catalysts, too, have come to be used as a catalyst for the polymerization of α -olefins having 3 to 10 carbon atoms to industrially produce olefin polymers. The metallocene catalysts, most of which are a single
15 metal complex, have a uniform active site, unlike the Ziegler-Natta catalysts. Thus, the metallocene catalysts have an advantage that in the copolymerization of ethylene and an α -olefin having 3 to 10 carbon atoms, they allow the resultant copolymers to contain the α -olefin in a uniform proportion and
20 to have a narrow composition distribution and have a high quality. Moreover, by converting a ligand structure of the metal complex, the C3-10 α -olefin sequence can be controlled to high degree. For example, in the polymerization of C3, propylene to produce polypropylene, the metallocene catalysts

have characteristics to produce highly isotactic polypropylene as is the case with the Ziegler-Natta catalysts, but do not by-produce atactic polypropylene.

[0004]

5 In using the metallocene catalysts for the polymerization of propylene thereby producing isotactic polypropylene, adding hydrogen into the reaction system in order to obtain a desirable molecular weight is known. It has been reported that adding hydrogen improves catalyst activity, and it has been explained
10 that this is because a dormant catalyst species with propylene 2,1-insertion is reactivated by hydrogen (Non-Patent Literature 1). On the other hand, the more hydrogen is added, the lower the molecular weight of the resultant polypropylene becomes. Thus, especially when a high molecular weight is
15 desired, the utility of adding hydrogen and the application scope thereof are restricted.

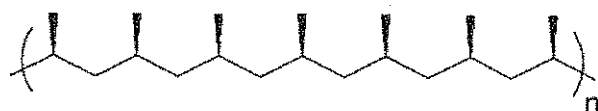
[0005]

 It has been reported that in using the metallocene catalysts to copolymerize propylene and a small amount of
20 ethylene thereby producing an isotactic polymer (random polypropylene), increasing the amount of ethylene to be added into the reaction system improves the catalyst activity (Non-Patent Literature 2). In this case, the resultant isotactic polypropylene, by including the ethylene unit in the

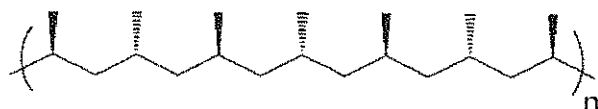
molecular chains, have lowered melting point. For this reason, especially when high heat resistance is desired, the addition amount of ethylene is restricted and moreover other physical properties are affected. In view of this, a method focusing
5 on the use of ethylene in order to achieve higher activity and then using ethylene in a small amount has been proposed (Patent Literature 1): specifically, adding a small amount of ethylene (preferably about 2 wt% or more) to a propylene polymerization reaction system that used a non-bridged metallocene catalyst
10 containing at least one kind of 2-aryllindene as a ligand improved catalyst activity. In the example disclosed in this report, using bis(2-(3,5-di-*t*-butylphenyl)indenyl)zirconiumdichloride to produce a random polypropylene having an ethylene content of
15 1.9 mol% achieved improved activity and allowed the polymer to have increased molecular weight compared with where ethylene was not added, but resulted in the polymer having a melting point that was lowered from 144°C to 137°C. Moreover, the resulting random polypropylene had tensile properties such that it showed
20 such elastomeric properties as uniform deformation to high elongation which is followed by high recovery from the elongation. That is, when high heat resistance is desired, the problem remains that the ethylene-addition amount is restricted and moreover other physical properties are affected. On the

other hand, there was a report in 1989 about a metallocene catalyst capable of producing a highly syndiotactic polypropylene that was not producible by the Ziegler-Natta catalysts (Non-Patent Literature 3): the highly syndiotactic polypropylene was produced through the polymerization of propylene utilizing a metallocene catalyst obtained by activating a Group IV transition metal compound with aluminoxane, the transition metal compound containing, as a ligand, isopropylidene(cyclopentadienyl)(9-fluorenyl) in which cyclopentadiene and fluorene are bridged by a carbon atom. The syndiotactic structure is under a "racemic" relationship in which substituents bonded to tertiary carbon (methyl groups in the case of propylene) are oriented in a direction alternating between one another, which relationship is in contrast with a "meso" relationship seen in the isotactic structure.

[0006]



Isotactic Polypropylene



Syndiotactic Polypropylene

[0007]

A polymer, when keeping an extended relationship of adjacent racemic chains, is highly syndiotactic. The above report defines the degree of the syndiotacticity using a proportion of a part having four consecutive racemic chains in the whole polymer, i.e., racemic pentad fraction. In the report, the highest racemic pentad fraction is 0.86: when this is converted to a simple racemic chain (racemic diad fraction), the racemic diad fraction is 0.96, which is significantly high. Furthermore, a polymer that is highly syndiotactic is crystalline. Since the racemic diad fraction and the racemic pentad fraction are proportional to the melting point (melting temperature) of the polymer, the polymer that has higher syndiotacticity generally shows higher melting point.

15 [0008]

The steric influence of such adjacent substituents is as follows. While the isotactic polypropylene adopts a helical secondary structure in which three molecules of propylene are present per turn of the helix to form crystals, it has been reported that the syndiotactic polypropylene, presumably because of the alternating orientation of substituents, can adopt plural energetically-stabilized crystal structures including helical structure and planar zigzag structure depending on heat history and stress history, and that between

some of these crystal structures, reversible phase transition is possible (Non-Patent Literature 4). Such difference in crystal structure greatly affects polymer material properties; it has been reported that the syndiotactic polypropylene shows characteristic thermal properties, physical properties and mechanical properties that differ from those of isotactic polypropylene. The difference in material properties caused by the difference between the syndiotactic structure and the isotactic structure is seen also in other α -olefin polymers. Thus, efficient production of polymers having a syndiotactic structure has been demanded.

Citation List

Patent Literature

[0009]

Patent Literature 1: JP-A-2002-505707

Non-Patent Literatures

[0010]

Non-Patent Literature 1: Macromol. Chem., Rapid Commun., 1993, 14, 97

Non-Patent Literature 2: Polymer, 1989, 30, 1350

Non-Patent Literature 3: J. Am. Chem. Soc., 1988, 110, 6255

Non-Patent Literature 4: Macromolecules, 1993, 26, 5711

Disclosure of the Invention

Problems to be Solved by the Invention

[0011]

The present inventors made their earnest studies and have
5 found out that by performing a production process allowing at
least one α -olefin having 3 to 10 carbon atoms and a small amount
of ethylene to be present in a specific ratio under a
polymerization reaction atmosphere, with the use of an olefin
polymerization catalyst comprising a bridged metallocene
10 compound with a specific structure, polymerization activity is
improved and the resultant syndiotactic α -olefin polymer has
increased molecular weight and high melting point. The present
invention has been completed based on this finding.

15 Means for Solving the Problems

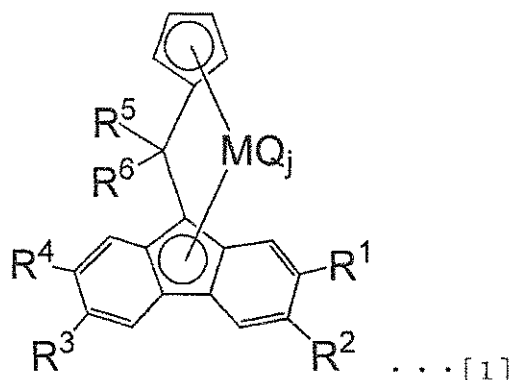
[0012]

That is, the present invention is directed to a process
for producing a syndiotactic α -olefin polymer comprising
polymerizing a monomer that comprises at least one α -olefin
20 having 3 to 10 carbon atoms and a small amount of ethylene, in
the presence of an olefin polymerization catalyst comprising
a transition metal compound (A) represented by the following
general formula [1], at least one compound (B) selected from
an organoaluminum oxy-compound (b-1), a compound (b-2) that

reacts with the transition metal compound (A) to form an ion pair and an organoaluminum compound (b-3),

which process for producing a syndiotactic α -olefin polymer satisfies the relationship: $0.001 \leq P_E/P_0 \leq 0.030$,
 5 provided that the molar amounts of ethylene and an α -olefin having 3 to 10 carbon atoms that are fed into a polymerization reactor under a polymerization temperature of not lower than 25°C are P_E and P_0 , respectively.

[0013]



10

[0014]

In the general formula [1], four groups: R^1 , R^2 , R^3 and R^4 are selected from the group consisting of a hydrogen atom, a hydrocarbon group and a silicon-containing group, and may be
 15 the same as or different from one another; R^1 and R^2 are not bonded to each other to form a ring; R^3 and R^4 are not bonded to each other to form a ring; R^5 and R^6 are each an atom or a substituent selected from the group consisting of a hydrogen atom, a hydrocarbon group having 2 to 20 carbon atoms and a

silicon-containing group, and may be the same as or different from one another; M is selected from a titanium atom, a zirconium atom and a hafnium atom; Q is a halogen atom, a hydrocarbon group, a neutral and conjugated or non-conjugated diene having 10 or less carbon atoms, an anionic ligand or a neutral ligand capable of coordination by lone pair electrons; j is an integer of 1 to 4, and when j is 2 or more, the plurality of Q may be the same as or different from one another.

10 Effect of the Invention

[0015]

The olefin polymer production process of the present invention improves polymerization activity and allows the α -olefin polymer to have increased molecular weight as compared with production processes that do not include a small amount of ethylene, and allows the resultant syndiotactic α -olefin polymer to maintain high melting point.

[0016]

Furthermore, the use of the olefin polymerization catalyst comprising the transition metal compound according to the present invention can produce a syndiotactic α -olefin polymer having high molecular weight in the polymerization at an industrially-possible temperature.

Best Mode for Carrying out the Invention

[0017]

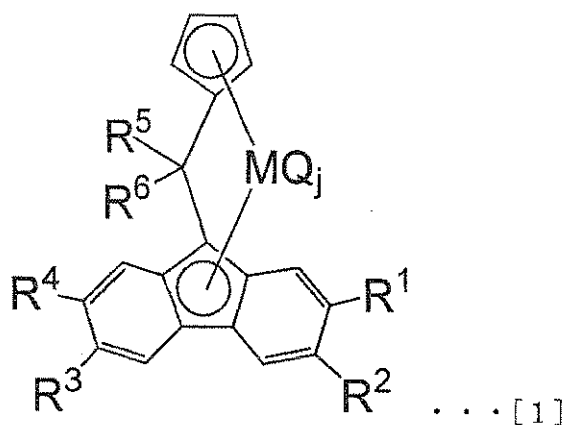
Hereinafter, preferred embodiments for carrying out the present invention are sequentially described with reference to
5 a transition metal compound (A), an organometallic compound (B), an olefin polymerization catalyst comprising both of these components, and a process for polymerizing olefins in the presence of this olefin polymerization catalyst.

[0018]

10 <Transition metal compound component (A)>

The transition metal compound component (A) comprises a transition metal compound represented by the following general formula [1]. The transition metal compound (A) is a bridged metallocene compound. The transition metal compound component
15 (A) can catalyze the polymerization of α -olefins having 3 to 10 carbon atoms with high polymerization activity when the relationship: $0.001 \leq P_E/P_O \leq 0.030$ is satisfied provided that the molar amounts of ethylene and an α -olefin having 3 to 10 carbon atoms that are fed into a polymerization reactor are P_E and P_O ,
20 respectively. The α -olefin polymer obtained has highly syndiotactic α -olefin chains, and has high molecular weight and high melting point that are well balanced.

[0019]



[0020]

In the formula [1], four groups: R^1 , R^2 , R^3 and R^4 are selected from the group consisting of a hydrogen atom, a hydrocarbon group and a silicon-containing group, and may be the same as or different from one another; R^1 and R^2 are not bonded to each other to form a ring; and R^3 and R^4 are not bonded to each other to form a ring. It is more preferable that R^1 and R^4 are the same atom or the same group, and R^2 and R^3 are the same atom or the same group; and it is particularly preferable that R^2 and R^3 are t-butyl groups.

[0021]

In the formula [1], R^5 and R^6 are each an atom or a substituent selected from the group consisting of a hydrogen atom, a hydrocarbon group having 2 to 20 carbon atoms and a silicon-containing group, and may be the same as or different from one another. It is more preferable that R^5 and R^6 are hydrocarbon groups having 6 to 20 carbon atoms.

[0022]

Examples of the hydrocarbon group having 6 to 20 carbon atoms include:

aryl groups such as phenyl group and naphthyl group;

alkylaryl groups such as o-tolyl group, m-tolyl group,
5 p-tolyl group, ethylphenyl group, n-propylphenyl group,
i-propylphenyl group, n-butylphenyl group, s-butylphenyl
group, t-butylphenyl group and xylyl group;

chloroaryl groups such as o-chlorophenyl group,
m-chlorophenyl group, p-chlorophenyl group and chloronaphthyl
10 group;

bromoaryl groups such as o-bromophenyl group,
m-bromophenyl group, p-bromophenyl group and bromonaphthyl
group;

bromoalkylaryl groups such as bromomethylphenyl group
15 and dibromomethylphenyl group;

iodoaryl groups such as o-iodophenyl group, m-iodophenyl
group, p-iodophenyl group and iodonaphthyl group;

iodoalkylaryl groups such as iodomethylphenyl group and
diiodomethylphenyl group;

20 aralkyl groups such as benzyl group, α -phenethyl group,
 β -phenethyl group, diphenylmethyl group, naphthylmethyl group
and neophyl group; and

halogenated benzyl groups such as m-chlorobenzyl group,
p-chlorobenzyl group, m-bromobenzyl group, p-bromobenzyl

group, m-iodobenzyl group and p-iodobenzyl group.

[0023]

R^1 and R^4 are each preferably a hydrogen atom or a hydrocarbon group having 6 to 20 carbon atoms; more preferably
5 a hydrogen atom or an aryl group having 6 to 10 carbon atoms; particularly preferably a hydrogen atom, phenyl group, o-tolyl group, m-tolyl group, p-tolyl group, o-chlorophenyl group, m-chlorophenyl group or p-chlorophenyl group.

[0024]

10 R^5 and R^6 may be the same as or different from one another, and are each preferably an aryl group having 6 to 10 carbon atoms or an aralkyl group having 6 to 10 carbon atoms; particularly preferably, phenyl group, benzyl group, m-chlorophenyl group, p-chlorophenyl group, m-chlorobenzyl group or p-chlorobenzyl
15 group.

[0025]

M is titanium, zirconium or hafnium, preferably zirconium or hafnium, particularly preferably zirconium.

[0026]

20 Q is an atom or a group selected from a halogen atom, a hydrocarbon group, an anionic ligand or a neutral ligand capable of coordination by lone pair electrons. Qs may be the same as or different from one another.

[0027]

Specific examples of the halogen atom include fluorine, chlorine, bromine and iodine. Specific examples of the hydrocarbon group include methyl, ethyl, n-propyl, isopropyl, 2-methylpropyl, 1,1-dimethylpropyl, 2,2-dimethylpropyl, 1,1-diethylpropyl, 1-ethyl-1-methylpropyl, 1,1,2,2-tetramethylpropyl, sec-butyl, tert-butyl, 1,1-dimethylbutyl, 1,1,3-trimethylbutyl, neopentyl, cyclohexylmethyl, cyclohexyl, 1-methyl-1-cyclohexyl, s-cis- or s-trans- η^4 -1,3-butadiene, s-cis- or s-trans- η^4 -1,4-diphenyl-1,3-butadiene, s-cis- or s-trans- η^4 -3-methyl-1,3-pentadiene, s-cis- or s-trans- η^4 -1,4-dibenzyl-1,3-butadiene, s-cis- or s-trans- η^4 -2,4-hexadiene, s-cis- or s-trans- η^4 -1,3-pentadiene, s-cis- or s-trans- η^4 -1,4-ditolyl-1,3-butadiene and s-cis- or s-trans- η^4 -1,4-bis(trimethylsilyl)-1,3-butadiene.

[0028]

Specific examples of the anionic ligand include alkoxy groups such as methoxy, tert-butoxy and phenoxy; carboxylate groups such as acetate and benzoate; and sulfonate groups such as mesylate and tosylate. Specific examples of the neutral ligand capable of coordination by lone pair electrons include organophosphorus compounds such as trimethylphosphine, triethylphosphine, triphenylphosphine and diphenylmethylphosphine; and ethers such as tetrahydrofuran,

diethylether, dioxane and 1,2-dimethoxyethane.

[0029]

A preferred embodiment of Q is a halogen atom or an alkyl group having 1 to 5 carbon atoms.

5 [0030]

j is an integer of 1 to 4, preferably 2.

[0031]

Transition metal compound (A) and examples thereof

Hereinafter, specific examples of the transition metal compound (A) represented by the general formula [1] in the present invention are described, without limiting the scope of the present invention.

[0032]

Specific examples of the transition metal compound (A) represented by the general formula [1] in the present invention include:

dibenzylmethylene(cyclopentadienyl)(2,7-dimethyl-3,6-di-tert-butylfluorenyl)zirconiumdichloride [also referred to as 1,3-diphenylisopropylidene

20 (cyclopentadienyl)(2,7-dimethyl-3,6-di-tert-butylfluorenyl)zirconiumdichloride; hereinafter, alias of each compound is omitted],

dibenzylmethylene(cyclopentadienyl(2,7-di(2,4,6-trimethylphenyl)-3,6-di-tert-butylfluorenyl)zirconiumdichloride,

dibenzylmethylene(cyclopentadienyl) (2,7-diphenyl-3,6-di-tert-butylfluorenyl) zirconiumdichloride,

dibenzylmethylene(cyclopentadienyl) (2,7-di(3,5-dimethylphenyl)-3,6-di-tert-butylfluorenyl) zirconiumdichloride,

5 dibenzylmethylene(cyclopentadienyl) (2,7-di(4-methylphenyl)-3,6-di-tert-butylfluorenyl) zirconiumdichloride,

dibenzylmethylene(cyclopentadienyl) (2,7-dinaphthyl-3,6-di-tert-butylfluorenyl) zirconiumdichloride,

dibenzylmethylene(cyclopentadienyl) (2,7-di(4-tert-butylphenyl)-3,6-di-tert-butylfluorenyl) zirconiumdichloride,

diphenethylmethylene(cyclopentadienyl) (2,7-diphenyl-3,6-di-tert-butylfluorenyl) zirconiumdichloride,

di(benzhydryl)methylene(cyclopentadienyl) (2,7-diphenyl-3,6-di-tert-butylfluorenyl) zirconiumdichloride,

15 di(cumyl)methylene(cyclopentadienyl) (2,7-diphenyl-3,6-di-tert-butylfluorenyl) zirconiumdichloride,

diphenylmethylene(cyclopentadienyl) (3,6-di-tert-butylfluorenyl) zirconiumdichloride,

di-o-tolylmethylene(cyclopentadienyl) (3,6-di-tert-butylfluorenyl) zirconiumdichloride,

di-m-tolylmethylene(cyclopentadienyl) (3,6-di-tert-butylfluorenyl) zirconiumdichloride,

di-p-tolylmethylene(cyclopentadienyl) (3,6-di-tert-butylfluorenyl) zirconiumdichloride,

di(o-chlorophenyl)methylene(cyclopentadienyl)(3,6-di-tert-butylfluorenyl)zirconiumdichloride,

di(m-chlorophenyl)methylene(cyclopentadienyl)(3,6-di-tert-butylfluorenyl)zirconiumdichloride,

5 di(p-chlorophenyl)methylene(cyclopentadienyl)(3,6-di-tert-butylfluorenyl)zirconiumdichloride,

di(o-bromophenyl)methylene(cyclopentadienyl)(3,6-di-tert-butylfluorenyl)zirconiumdichloride,

10 di(m-bromophenyl)methylene(cyclopentadienyl)(3,6-di-tert-butylfluorenyl)zirconiumdichloride,

di(p-bromophenyl)methylene(cyclopentadienyl)(3,6-di-tert-butylfluorenyl)zirconiumdichloride,

di(o-iodophenyl)methylene(cyclopentadienyl)(3,6-di-tert-butylfluorenyl)zirconiumdichloride,

15 di(m-iodophenyl)methylene(cyclopentadienyl)(3,6-di-tert-butylfluorenyl)zirconiumdichloride,

di(p-iodophenyl)methylene(cyclopentadienyl)(3,6-di-tert-butylfluorenyl)zirconiumdichloride,

20 di(o-trifluoromethylphenyl)methylene(cyclopentadienyl)(3,6-di-tert-butylfluorenyl)zirconiumdichloride,

di(m-trifluoromethylphenyl)methylene(cyclopentadienyl)(3,6-di-tert-butylfluorenyl)zirconiumdichloride,

di(p-trifluoromethylphenyl)methylene(cyclopentadienyl)(3,6-di-tert-butylfluorenyl)zirconiumdichloride,

di(2-naphthyl)methylene(cyclopentadienyl)(3,6-di-tert-butyl
fluorenyl)zirconiumdichloride,

dibenzylmethylene(cyclopentadienyl)(3,6-di-tert-butylfluore
nyl)zirconiumdichloride,

5 di(o-chlorobenzyl)methylene(cyclopentadienyl)(3,6-di-tert-b
utylfluorenyl)zirconiumdichloride,

di(m-chlorobenzyl)methylene(cyclopentadienyl)(3,6-di-tert-b
utylfluorenyl)zirconiumdichloride,

10 di(p-chlorobenzyl)methylene(cyclopentadienyl)(3,6-di-tert-b
utylfluorenyl)zirconiumdichloride,

di(o-bromobenzyl)methylene(cyclopentadienyl)(3,6-di-tert-bu
tylfluorenyl)zirconiumdichloride,

di(m-bromobenzyl)methylene(cyclopentadienyl)(3,6-di-tert-bu
tylfluorenyl)zirconiumdichloride,

15 di(p-bromobenzyl)methylene(cyclopentadienyl)(3,6-di-tert-bu
tylfluorenyl)zirconiumdichloride,

di(o-iodobenzyl)methylene(cyclopentadienyl)(3,6-di-tert-but
ylfluorenyl)zirconiumdichloride,

20 di(m-iodobenzyl)methylene(cyclopentadienyl)(3,6-di-tert-but
ylfluorenyl)zirconiumdichloride,

di(p-iodobenzyl)methylene(cyclopentadienyl)(3,6-di-tert-but
ylfluorenyl)zirconiumdichloride,

di(o-methylbenzyl)methylene(cyclopentadienyl)(3,6-di-tert-b
utylfluorenyl)zirconiumdichloride,

di(m-methylbenzyl)methylene(cyclopentadienyl)(3,6-di-tert-butylfluorenyl)zirconiumdichloride,

di(p-methylbenzyl)methylene(cyclopentadienyl)(3,6-di-tert-butylfluorenyl)zirconiumdichloride,

5 (benzyl)(phenyl)methylene(cyclopentadienyl)(3,6-di-tert-butylfluorenyl)zirconiumdichloride,

(benzyl)(phenyl)methylene(cyclopentadienyl)(2,7-diphenyl-3,6-di-tert-butylfluorenyl)zirconiumdichloride,

(benzyl)(phenyl)methylene(cyclopentadienyl)(2,7-di-o-tolyl-3,6-di-tert-butylfluorenyl)zirconiumdichloride,

(benzyl)(phenyl)methylene(cyclopentadienyl)(2,7-di-p-chlorophenyl-3,6-di-tert-butylfluorenyl)zirconiumdichloride,

(p-chlorobenzyl)(phenyl)methylene(cyclopentadienyl)(2,7-diphenyl-3,6-di-tert-butylfluorenyl)zirconiumdichloride,

15 (p-chlorobenzyl)(phenyl)methylene(cyclopentadienyl)(2,7-di-o-tolyl-3,6-di-tert-butylfluorenyl)zirconiumdichloride,

(p-chlorobenzyl)(phenyl)methylene(cyclopentadienyl)(2,7-di-p-chlorophenyl-3,6-di-tert-butylfluorenyl)zirconiumdichloride,

20 (benzyl)(p-chlorophenyl)methylene(cyclopentadienyl)(2,7-diphenyl-3,6-di-tert-butylfluorenyl)zirconiumdichloride,

(benzyl)(p-chlorophenyl)methylene(cyclopentadienyl)(2,7-di-o-tolyl-3,6-di-tert-butylfluorenyl)zirconiumdichloride,

(benzyl)(p-chlorophenyl)methylene(cyclopentadienyl)(2,7-di-

p-chlorophenyl-3,6-di-tert-butylfluorenyl) zirconiumdichloride,

diphenylmethene(cyclopentadienyl) (2,7-di-o-tolyl-3,6-di-tert-butylfluorenyl) zirconiumdichloride,

5 di-p-tolyl-methene(cyclopentadienyl) (2,7-di-o-tolyl-3,6-di-tert-butylfluorenyl) zirconiumdichloride,

di(p-chlorophenyl)methene(cyclopentadienyl) (2,7-di-o-tolyl-3,6-di-tert-butylfluorenyl) zirconiumdichloride,

10 di(p-trifluoromethylphenyl)methene(cyclopentadienyl) (2,7-di-o-tolyl-3,6-di-tert-butylfluorenyl) zirconiumdichloride,

di(2-naphthyl)methene(cyclopentadienyl) (2,7-di-o-tolyl-3,6-di-tert-butylfluorenyl) zirconiumdichloride,

dibenzylmethene(cyclopentadienyl) (2,7-di-o-tolyl-3,6-di-tert-butylfluorenyl) zirconiumdichloride,

15 di(p-chlorobenzyl)methene(cyclopentadienyl) (2,7-di-o-tolyl-3,6-di-tert-butylfluorenyl) zirconiumdichloride,

di(p-methylbenzyl)methene(cyclopentadienyl) (2,7-di-o-tolyl-3,6-di-tert-butylfluorenyl) zirconiumdichloride,

20 dibenzylmethene(cyclopentadienyl) (2,7-di-o-tolyl-fluorenyl) zirconiumdichloride,

dibenzylmethene(cyclopentadienyl) [2,7-di-(o-ethylphenyl)-3,6-di-tert-butylfluorenyl] zirconiumdichloride,

dibenzylmethene(cyclopentadienyl) [2,7-di-[o-(n-propyl)phenyl]-3,6-di-tert-butylfluorenyl] zirconiumdichloride,

dibenzylmethylenecyclopentadienyl [2,7-di-[o-(iso-propyl)phenyl]-3,6-di-tert-butylfluorenyl]zirconiumdichloride,
dibenzylmethylenecyclopentadienyl [2,7-di-[o-(n-butyl)phenyl]-3,6-di-tert-butylfluorenyl]zirconiumdichloride,
5 dibenzylmethylenecyclopentadienyl [2,7-di-[o-(iso-butyl)phenyl]-3,6-di-tert-butylfluorenyl]zirconiumdichloride,
dibenzylmethylenecyclopentadienyl [2,7-di-[o-(sec-butyl)phenyl]-3,6-di-tert-butylfluorenyl]zirconiumdichloride,
dibenzylmethylenecyclopentadienyl [2,7-di-[o-(tert-butyl)phenyl]-3,6-di-tert-butylfluorenyl]zirconiumdichloride,
10 dibenzylmethylenecyclopentadienyl [2,7-di-[o-(n-icosyl)phenyl]-3,6-di-tert-butylfluorenyl]zirconiumdichloride,
dibenzylmethylenecyclopentadienyl [2,7-di-[o-(cyclohexyl)phenyl]-3,6-di-tert-butylfluorenyl]zirconiumdichloride,
15 dibenzylmethylenecyclopentadienyl [2,7-di-(biphenyl-2-yl)-3,6-di-tert-butylfluorenyl]zirconiumdichloride,
dibenzylmethylenecyclopentadienyl [2,7-di-[o-(2-naphthyl)phenyl]-3,6-di-tert-butylfluorenyl]zirconiumdichloride,
dibenzylmethylenecyclopentadienyl
20 [2,7-di-[o-(2-phenanthryl)phenyl]-3,6-di-tert-butylfluorenyl]zirconiumdichloride,
dibenzylmethylenecyclopentadienyl [2,7-di-(o-trimethylsilylphenyl)-3,6-di-tert-butylfluorenyl]zirconiumdichloride,
dibenzylmethylenecyclopentadienyl [2,7-di-(o-triphenylsilyl

lphenyl)-3,6-di-tert-butylfluorenyl] zirconiumdichloride,
 diphenylmethylene(cyclopentadienyl) (2,7-diphenyl-3,6-di-ter
 t-butylfluorenyl) zirconiumdichloride,
 dibenzylmethylene(cyclopentadienyl) (2,7-diphenyl-3,6-di-ter
 5 t-butylfluorenyl) zirconiumdichloride,
 diphenylmethylene(cyclopentadienyl) (2,7-di-p-chlorophenyl-3
 ,6-di-tert-butylfluorenyl) zirconiumdichloride,
 di-p-tolyl-methylene(cyclopentadienyl) (2,7-di-p-chloropheny
 l-3,6-di-tert-butylfluorenyl) zirconiumdichloride,
 10 di(p-chlorophenyl)methylene(cyclopentadienyl) (2,7-di-p-chlo
 rophenyl-3,6-di-tert-butylfluorenyl) zirconiumdichloride,
 di(p-trifluoromethylphenyl)methylene(cyclopentadienyl) (2,7-
 di-p-chlorophenyl-3,6-di-tert-butylfluorenyl) zirconiumdichl
 oride,
 15 di(2-naphthyl)methylene(cyclopentadienyl) (2,7-di-p-chloroph
 enyl-3,6-di-tert-butylfluorenyl) zirconiumdichloride,
 dibenzylmethylene(cyclopentadienyl) (2,7-di-p-chlorophenyl-3
 ,6-di-tert-butylfluorenyl) zirconiumdichloride,
 di(p-chlorobenzyl)methylene(cyclopentadienyl) (2,7-di-p-chlo
 20 rophenyl-3,6-di-tert-butylfluorenyl) zirconiumdichloride,
 di(p-methylbenzyl)methylene(cyclopentadienyl) (2,7-di-p-chlo
 rophenyl-3,6-di-tert-butylfluorenyl) zirconiumdichloride,
 dibenzylmethylene(cyclopentadienyl) (2,7-di-p-chlorophenyl-3
 ,6-ditrimethylsilylfluorenyl) zirconiumdichloride,

dibenzylmethylenecyclopentadienyl (2,7-di-p-chlorophenyl-3,6-dicumylfluorenyl) zirconiumdichloride,
dibenzylmethylenecyclopentadienyl (2,7-di-p-chlorophenyl-3,6-adamantylfluorenyl) zirconiumdichloride,
5 dimethylmethylenecyclopentadienyl (2,7-di-p-trifluoromethylphenyl-3,6-di-tert-butylfluorenyl) zirconiumdichloride,
diethylmethylenecyclopentadienyl (2,7-di-p-trifluoromethylphenyl-3,6-di-tert-butylfluorenyl) zirconiumdichloride,
di-n-propylmethylenecyclopentadienyl (2,7-di-p-trifluoromethylphenyl-3,6-di-tert-butylfluorenyl) zirconiumdichloride,
10 di-iso-propylmethylenecyclopentadienyl (2,7-di-p-trifluoromethylphenyl-3,6-di-tert-butylfluorenyl) zirconiumdichloride,
di-n-butylmethylenecyclopentadienyl (2,7-di-p-trifluoromethylphenyl-3,6-di-tert-butylfluorenyl) zirconiumdichloride,
15 di-iso-butylmethylenecyclopentadienyl (2,7-di-p-trifluoromethylphenyl-3,6-di-tert-butylfluorenyl) zirconiumdichloride,
di-sec-butylmethylenecyclopentadienyl (2,7-di-p-trifluoromethylphenyl-3,6-di-tert-butylfluorenyl) zirconiumdichloride,
di-tert-butylmethylenecyclopentadienyl (2,7-di-p-trifluoromethylphenyl-3,6-di-tert-butylfluorenyl) zirconiumdichloride,
20 di-n-octylmethylenecyclopentadienyl (2,7-di-p-trifluoromethylphenyl-3,6-di-tert-butylfluorenyl) zirconiumdichloride,
di-n-triacontylmethylenecyclopentadienyl (2,7-di-p-trifluoromethylphenyl-3,6-di-tert-butylfluorenyl) zirconiumdichloride,

de,

phenylmethylene(cyclopentadienyl) (2,7-di-p-trifluoromethylp
henyl-3,6-di-tert-butylfluorenyl) zirconiumdichloride,

diphenylmethylene(cyclopentadienyl) (2,7-di-p-trifluoromethy

5 lphenyl-3,6-di-tert-butylfluorenyl) zirconiumdichloride,

di-p-tolylmethylene(cyclopentadienyl) (2,7-di-p-trifluoromet
hylphenyl-3,6-di-tert-butylfluorenyl) zirconiumdichloride,

di(p-chlorophenyl)methylene(cyclopentadienyl) (2,7-di-p-trif
luoromethylphenyl-3,6-di-tert-butylfluorenyl) zirconiumdichl

10 oride,

di(p-trifluoromethylphenyl)methylene(cyclopentadienyl) (2,7-
di-p-trifluoromethylphenyl-3,6-di-tert-butylfluorenyl) zirco
niumdichloride,

di(2-naphthyl)methylene(cyclopentadienyl) (2,7-di-p-trifluor

15 omethylphenyl-3,6-di-tert-butylfluorenyl) zirconiumdichlorid
e,

dibenzylmethylene(cyclopentadienyl) (2,7-di-p-trifluoromethy
lphenyl-3,6-di-tert-butylfluorenyl) zirconiumdichloride,

di(p-chlorobenzyl)methylene(cyclopentadienyl) (2,7-di-p-trif

20 luoromethylphenyl-3,6-di-tert-butylfluorenyl) zirconiumdichl
oride,

di(p-methylbenzyl)methylene(cyclopentadienyl) (2,7-di-p-trif
luoromethylphenyl-3,6-di-tert-butylfluorenyl) zirconiumdichl

oride; compounds in which a zirconium atom of the above

compounds is replaced with a hafnium atom or a titanium atom;
compounds in which a chlorine atom of the above compounds is
replaced with methyl group or benzyl group; and combinations
thereof, without being limited thereto. Among a hafnium atom,
5 a zirconium atom and a titanium atom, preferable is a zirconium
atom. These compounds may be used singly, or two or more kinds
may be used in combination.

[0033]

Production process of transition metal compound (A)

10 The transition metal compound (A) used in the present
invention can be produced by known methods without limitation.
Exemplary methods are described in JP-A-2000-212194,
JP-A-2004-168744, JP-A-2004-189666, JP-A-2004-161957,
JP-A-2007-302854, JP-A-2007-302853, WO01/027124,
15 JP-A-2001-526730 and JP-A-H10-226694.

[0034]

Preferred embodiments when transition metal compound (A) is
subjected to olefin polymer production

There are described hereinbelow preferred embodiments
20 when the transition metal compound (A) employed in the present
invention is used as a catalyst for the production of olefin
polymers (olefin polymerization catalyst).

[0035]

<Olefin polymerization catalyst>

When the transition metal compound (A) is used as the olefin polymerization catalyst, the catalyst comprises the transition metal compound (A) and an organometallic compound (B). Here, the organometallic compound (B) is at least one
5 organometallic compound (B) selected from the following compounds (b-1), (b-2) and (b-3).

[0036]

(b-1) organoaluminum oxy-compound

(b-2) compound that reacts with the transition metal
10 compound (A) to form an ion pair

(b-3) organoaluminum compound

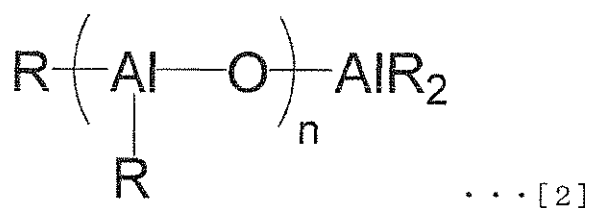
The compounds (b-1), (b-2) and (b-3) each may be used singly, or two or more kinds may be used in combination. The olefin polymerization catalyst may further comprise a
15 particulate carrier (C) and an organic compound component (D) as required. Hereinafter, the individual components are specifically described.

[0037]

[Organoaluminum oxy-compound (b-1)]

20 As the organoaluminum oxy-compound (b-1) used in the present invention, hitherto publicly known aluminoxane may be used as it is. Specifically, exemplary compounds are those represented by the following general formula [2]:

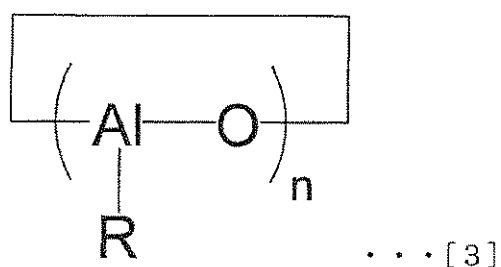
[0038]



[0039]

and/or the following general formula [3]:

[0040]



5

[0041]

In the general formulae [2] and [3], R is a hydrocarbon group having 1 to 10 carbon atoms; and n is an integer of 2 or more. Compounds represented by the formulae in which R is methyl group and n is 3 or more, preferably 10 or more are used suitably as methylaluminoxane (MAO). Mixing of organoaluminum compounds into these aluminosanes is permitted.

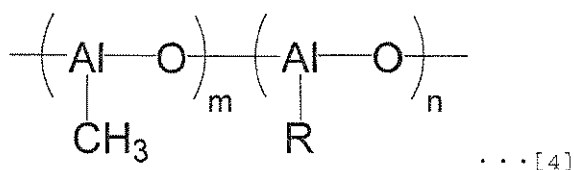
10

[0042]

As the organoaluminum oxy-compound (b-1) used in the present invention, further examples include such modified methylaluminoxane as represented by the following general formula [4].

15

[0043]



[0044]

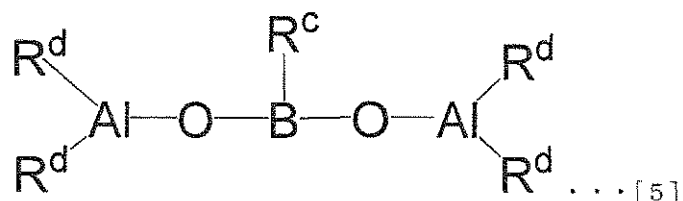
In the formula, R is a hydrocarbon group having 2 to 10 carbon atoms; and m and n are each an integer of 2 or more. The modified methylaluminoxane is prepared using trimethylaluminum and an alkylaluminum other than trimethylaluminum. Such a compound as represented by the formula [4] is generally referred to as MMAO. The MMAO can be prepared by the process described in US4960878 and US5041584.

Further, compounds prepared by using trimethylaluminum and tri-isobutyl aluminum which is represented by the above formula wherein R is isobutyl group are commercially available under the name of MMAO or TMAO from Tosoh Finechem Corporation and the like. The MMAO is an aluminoxane which has improved storage stability and improved solubility in various kinds of solvents; specifically, it dissolves in an aliphatic or alicyclic hydrocarbon, unlike the MAO of the formula [2] or [3].

[0045]

Further examples of the organoaluminum oxy-compound (b-1) used in the present invention include boron-containing organoaluminum oxy-compounds represented by the following general formula [5].

[0046]



[0047]

In the formula, R^c is a hydrocarbon group having 1 to 10 carbon atoms; and R^d may be the same as or different from one another, and are each a hydrogen atom, a halogen atom or a hydrocarbon group having 1 to 10 carbon atoms.

The organoaluminum oxy-compounds represented by the general formulae [2] to [5] may be used singly, or two or more kinds may be used in combination.

[0048]

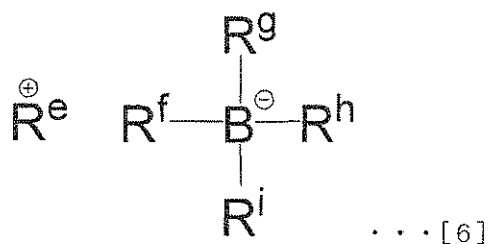
[Compound (b-2) that reacts with transition metal compound (A) to form an ion pair]

Examples of the compound (b-2) that reacts with the transition metal compound (A) to form an ion pair (hereinafter, also abbreviated as an "ionic compound") include Lewis acids, ionic compounds, borane compounds and carborane compounds as described 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 examples include heteropoly compounds and isopoly compounds.

[0049]

The ionic compound (b-2) that is preferably employed in the present invention is a borate compound represented by the following general formula [6].

[0050]



5

[0051]

In the formula, R^{e+} is, for example, H^+ , carbenium cation, oxonium cation, ammonium cation, phosphonium cation, cycloheptyltrienyl cation or ferrocenium cation having a transition metal; and R^f to R^i may be the same as or different from each other and are each an organic group, preferably an aryl group.

Examples of the carbenium cation include tri-substituted carbenium cations such as triphenylcarbenium cation, tris(methylphenyl)carbenium cation and tris(dimethylphenyl)carbenium cation.

15

[0052]

Examples of the ammonium cation include trialkylammonium cations such as trimethylammonium cation, triethylammonium cation, tri(n-propyl)ammonium cation, triisopropylammonium cation, tri(n-butyl)ammonium cation and triisobutylammonium

20

cation; N,N-dialkylanilinium cations such as
 N,N-dimethylanilinium cation, N,N-diethylanilinium cation
 and N,N,2,4,6-pentamethylanilinium cation; and
 dialkylammonium cations such as diisopropylammonium cation
 5 and dicyclohexylammonium cation.

[0053]

Examples of the phosphonium cation include
 triarylphosphonium cations such as triphenylphosphonium
 cation, tris(methylphenyl)phosphonium cation and
 10 tris(dimethylphenyl)phosphonium cation.

[0054]

Of the above, R^{e+} is preferably carbenium cation or
 ammonium cation; particularly preferably triphenylcarbenium
 cation, N,N-dimethylanilinium cation or N,N-diethylanilinium
 15 cation.

[0055]

Specific examples of carbenium salts include
 triphenylcarbenium tetrphenylborate, triphenylcarbenium
 tetrakis(pentafluorophenyl)borate, triphenylcarbenium
 20 tetrakis(3,5-ditrifluoromethylphenyl)borate,
 tris(4-methylphenyl)carbenium
 tetrakis(pentafluorophenyl)borate and
 tris(3,5-dimethylphenyl)carbenium
 tetrakis(pentafluorophenyl)borate.

[0056]

Examples of ammonium salts include trialkyl-substituted ammonium salts, N,N-dialkylanilinium salts and dialkylammonium salts.

5 [0057]

Specific examples of the trialkyl-substituted ammonium salts include triethylammoniumtetraphenylborate, tripropylammoniumtetraphenylborate, tri(n-butyl)ammoniumtetraphenylborate, 10 trimethylammoniumtetrakis(p-tolyl)borate, trimethylammoniumtetrakis(o-tolyl)borate, tri(n-butyl)ammoniumtetrakis(pentafluorophenyl)borate, triethylammoniumtetrakis(pentafluorophenyl)borate, tripropylammoniumtetrakis(pentafluorophenyl)borate, 15 tripropylammoniumtetrakis(2,4-dimethylphenyl)borate, tri(n-butyl)ammoniumtetrakis(3,5-dimethylphenyl)borate, tri(n-butyl)ammoniumtetrakis(4-trifluoromethylphenyl)borate, tri(n-butyl)ammoniumtetrakis(3,5-ditrifluoromethylphenyl)borate, tri(n-butyl)ammoniumtetrakis(o-tolyl)borate, 20 dioctadecylmethyammoniumtetraphenylborate, dioctadecylmethyammoniumtetrakis(p-tolyl)borate, dioctadecylmethyammoniumtetrakis(o-tolyl)borate, dioctadecylmethyammoniumtetrakis(pentafluorophenyl)borate, dioctadecylmethyammoniumtetrakis(2,4-dimethylphenyl)borate,

dioctadecylmethyammoniumtetrakis(3,5-dimethylphenyl)borate,
 dioctadecylmethyammoniumtetrakis(4-trifluoromethylphenyl)b
 orate,
 dioctadecylmethyammoniumtetrakis(3,5-ditrifluoromethylphen
 5 yl)borate and dioctadecylmethyammonium.

[0058]

Specific examples of the N,N-dialkylanilinium salts
 include

N,N-dimethylaniliniumtetrphenylborate,

10 N,N-dimethylaniliniumtetrakis(pentafluorophenyl)borate,

N,N-dimethylaniliniumtetrakis(3,5-ditrifluoromethylphenyl)b
 orate, N,N-diethylaniliniumtetrphenylborate,

N,N-diethylaniliniumtetrakis(pentafluorophenyl)borate,

N,N-diethylaniliniumtetrakis(3,5-ditrifluoromethylphenyl)bo
 15 rate, N,N-2,4,6-pentamethylaniliniumtetrphenylborate and
 N,N-2,4,6-pentamethylaniliniumtetrakis(pentafluorophenyl)bo
 rate.

[0059]

Specific examples of the dialkylammonium salts include
 20 di(1-propyl)ammoniumtetrakis(pentafluorophenyl)borate and
 dicyclohexylammoniumtetrphenylborate.

[0060]

Furthermore, ionic compounds disclosed by the present
 applicant (JP-A-2004-51676) are employable without

limitation.

[0061]

The ionic compounds (b-2) may be used singly, or two or more kinds may be used in combination.

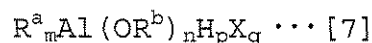
5 [0062]

[Organoaluminum compound (b-3)]

Examples of the organoaluminum compound (b-3) that forms the olefin polymerization catalyst include organoaluminum compounds represented by the following general formula [7] and
10 alkyl complex compounds containing a Group 1 metal and aluminum represented by the following general formula [8].

[0063]

Organoaluminum compounds represented by:



15 wherein R^a and R^b may be the same as or different from each other and are each a hydrocarbon group having 1 to 15 carbon atoms, preferably 1 to 4 carbon atoms; X is a halogen atom; $0 < m \leq 3$; $0 \leq n < 3$; $0 \leq p < 3$; $0 \leq q < 3$; and $m+n+p+q = 3$.

[0064]

20 Specific examples of such compounds include:

tri(n-alkyl)aluminums such as trimethylaluminum, triethylaluminum, tri(n-butyl)aluminum, tri(n-hexyl)aluminum and tri(n-octyl)aluminum;

branched-chain trialkylaluminums such as

triisopropylaluminum, triisobutylaluminum,
 tri(sec-butyl)aluminum, tri(tert-butyl)aluminum,
 tri(2-methylbutyl)aluminum, tri(3-methylhexyl)aluminum and
 tri(2-ethylhexyl)aluminum;

5 tricycloalkylaluminums such as tricyclohexylaluminum
 and tricyclooctylaluminum;

triarylaluminums such as triphenylaluminum and
 tritolylaluminum;

dialkylaluminumhydrides such as
 10 diisopropylaluminumhydride and diisobutylaluminumhydride;

alkenylaluminums such as those represented by the general
 formula: $(i-C_4H_9)_xAl_y(C_5H_{10})_z$ (wherein x, y and z are each a
 positive number, and $z \leq 2x$) with examples including
 isoprenylaluminum;

15 alkylaluminum alkoxides such as isobutylaluminum
 methoxide and isobutylaluminum ethoxide;

dialkylaluminum alkoxides such as dimethylaluminum
 methoxide, diethylaluminum ethoxide and dibutylaluminum
 butoxide;

20 alkylaluminum sesquialkoxides such as ethylaluminum
 sesquiethoxide and butylaluminum sesquibutoxide;

partially alkoxyated alkylaluminums such as those
 having an average composition represented by $R^{a}_{2.5}Al(OR^b)_{0.5}$;

alkylaluminum aryloxides such as diethylaluminum

phenoxide and
diethylaluminum(2,6-di-t-butyl-4-methylphenoxide);

dialkylaluminum halides such as dimethylaluminum
chloride, diethylaluminum chloride, dibutylaluminum chloride,
5 diethylaluminum bromide and diisobutylaluminum chloride;

alkylaluminum sesquihalides such as ethylaluminum
sesquichloride, butylaluminum sesquichloride and
ethylaluminum sesquibromide;

partially halogenated alkylaluminums such as
10 alkylaluminum dihalides including ethylaluminum dichloride;

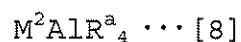
dialkylaluminum hydrides such as diethylaluminum hydride
and diisobutylaluminum hydride;

partially hydrogenated alkylaluminums such as
alkylaluminum dihydrides including ethylaluminum dihydride
15 and propylaluminum dihydride; and

partially alkoxyated and halogenated alkylaluminums
such as ethylaluminum ethoxychloride, butylaluminum
butoxychloride and ethylaluminum ethoxybromide.

[0065]

20 Alkyl complex compounds containing a Group 1 metal of the
periodic table and aluminum, represented by:



wherein M^2 is Li, Na or K; and R^a is a hydrocarbon group
having 1 to 15 carbon atoms, preferably 1 to 4 carbon atoms.

[0066]

Examples of such compounds include $\text{LiAl}(\text{C}_2\text{H}_5)_4$ and $\text{LiAl}(\text{C}_7\text{H}_{15})_4$.

[0067]

5 Compounds analogous to the compound represented by the general formula [8] are also employable. Examples of such compounds include organoaluminum compounds wherein two or more aluminum compounds are bonded via a nitrogen atom, such as $(\text{C}_2\text{H}_5)_2\text{AlN}(\text{C}_2\text{H}_5)\text{Al}(\text{C}_2\text{H}_5)_2$.

10 [0068]

In terms of easy availability, as the organoaluminum compound (b-3), triethylaluminum, triisobutylaluminum, tri(n-octyl)aluminum and diisobutylaluminumhydride are preferably used.

15 [0069]

The organoaluminum compounds (b-3) may be used singly, or two or more kinds may be used in combination.

[0070]

20 The olefin polymerization catalyst used in the present invention may further comprise a carrier (C) as required, together with the transition metal compound (A) and the organometallic compound (B).

[0071]

[Carrier (C)]

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

[0072]

Examples of the porous oxides include SiO_2 , Al_2O_3 , MgO , ZrO , TiO_2 , B_2O_3 , CaO , ZnO , BaO , ThO_2 , and composites or mixtures containing these oxides, such as natural or synthetic zeolite,
10 $\text{SiO}_2\text{-MgO}$, $\text{SiO}_2\text{-Al}_2\text{O}_3$, $\text{SiO}_2\text{-TiO}_2$, $\text{SiO}_2\text{-V}_2\text{O}_5$, $\text{SiO}_2\text{-Cr}_2\text{O}_3$ and $\text{SiO}_2\text{-TiO}_2\text{-MgO}$. Of these, oxides containing SiO_2 and/or Al_2O_3 as a main component are preferable. The porous oxides have different properties depending on the types and preparation processes. The carrier preferably used in the present
15 invention has a particle diameter of 10 to 300 μm , preferably 20 to 200 μm , a specific surface area of 50 to 1,000 m^2/g , preferably 100 to 700 m^2/g , and a pore volume of 0.3 to 3.0 cm^3/g . If necessary, the carrier may be calcined at 100 to 1,000°C, preferably at 150 to 700°C prior to use.

20 [0073]

Examples of the inorganic chlorides include MgCl_2 , MgBr_2 , MnCl_2 and MnBr_2 . The inorganic chlorides may be used as they are, or may be used after pulverized with, for example, a ball mill or a vibration mill. The inorganic chlorides may be used

after they are dissolved in a solvent such as alcohol and precipitated as fine particles with a precipitating agent.

[0074]

The clays used in the present invention are, usually,
 5 mainly composed of clay minerals. The ion-exchange layered compounds used in the present invention have crystal structures in which planes formed by ionic bonding or the like are stacked by weak bond energy in parallel and contain exchangeable ions. Most clay minerals are ion-exchange layered compounds. The
 10 clays, the clay minerals and the ion-exchange layered compounds that are employable are not limited to natural compounds but include synthetic products. Further examples of such clays, clay minerals and ion-exchange layered compounds include clays, clay minerals and ion crystalline compounds having layered
 15 crystal structures such as hexagonal closest packing structure, antimony structure, CdCl_2 structure and CdI_2 structure. Examples of the clays and the clay minerals include kaolin, bentonite, kibushi clay, gairome clay, allophane, hisingerite, pyrophyllite, mica, montmorillonite, vermiculite, chlorite,
 20 palygorskite, kaolinite, nacrite, dickite and halloysite. Examples of the ion-exchange layered compounds include crystalline acidic salts of polyvalent metals such as $\alpha\text{-Zr}(\text{HAsO}_4)_2 \cdot \text{H}_2\text{O}$, $\alpha\text{-Zr}(\text{HPO}_4)_2$, $\alpha\text{-Zr}(\text{KPO}_4)_2 \cdot 3\text{H}_2\text{O}$, $\alpha\text{-Ti}(\text{HPO}_4)_2$, $\alpha\text{-Ti}(\text{HAsO}_4)_2 \cdot \text{H}_2\text{O}$, $\alpha\text{-Sn}(\text{HPO}_4)_2 \cdot \text{H}_2\text{O}$, $\gamma\text{-Zr}(\text{HPO}_4)_2$, $\gamma\text{-Ti}(\text{HPO}_4)_2$ and

$\gamma\text{-Ti}(\text{NH}_4\text{PO}_4)_2 \cdot \text{H}_2\text{O}$. It is also preferable that the clays and the clay minerals used in the present invention are subjected to chemical treatments. As chemical treatments, for example, a surface treatment to remove impurities adhered on the surface and a treatment to affect the crystal structure of the clay are employable. Specific examples of such chemical treatments include acid treatment, alkali treatment, salt treatment and organic substance treatment.

[0075]

The ion-exchange layered compounds used in the present invention, by utilizing ion exchange properties and exchanging exchangeable ions between layers with other larger and bulkier ions, may be those having enlarged interlayer distance. The bulky ions play a pillar-like roll to support the layered structure and are generally called pillars. The introduction of other substances into between layers of the layered compounds is called intercalation. Examples of guest compounds to be intercalated include cationic inorganic compounds such as TiCl_4 and ZrCl_4 ; metal alkoxides such as $\text{Ti}(\text{OR})_4$, $\text{Zr}(\text{OR})_4$, $\text{PO}(\text{OR})_3$ and $\text{B}(\text{OR})_3$ (R is a hydrocarbon group or the like); and metal hydroxide ions such as $[\text{Al}_{13}\text{O}_4(\text{OH})_{24}]^{7+}$, $[\text{Zr}_4(\text{OH})_{14}]^{2+}$ and $[\text{Fe}_3\text{O}(\text{OCOCH}_3)_6]^+$. These compounds may be used singly, or two or more kinds may be used in combination. The intercalation of these compounds may be carried out in the presence of polymers

obtained by hydrolysis of metal alkoxides such as Si(OR)_4 , Al(OR)_3 and Ge(OR)_4 (R is a hydrocarbon group or the like) or in the presence of colloidal inorganic compounds such as SiO_2 . Examples of the pillars include oxides produced by
5 intercalation of the above metal hydroxide ions into between layers followed by thermal dehydration. Of these, the clays and the clay minerals are preferable; and montmorillonite, vermiculite, pectolite, taeniolite and synthetic mica are particularly preferable.

10 [0076]

Examples of the organic compounds as the carrier (C) include granular or fine particulate solids having a particle diameter of 10 to 300 μm . Specific examples of such compounds include (co)polymers produced by using α -olefins having 2 to
15 14 carbon atoms such as ethylene, propylene, 1-butene and 4-methyl-1-pentene as a main component; (co)polymers produced by using vinylcyclohexane or styrene as a main component; and modified products of these (co)polymers.

[0077]

20 The carriers (C) may be used singly, or two or more kinds may be used in combination.

[0078]

The olefin polymerization catalyst used in the present invention may further comprise an organic compound (D),

together with the transition metal compound (A) and the organometallic compound component (B), and the carrier (C) used as an optional component.

[0079]

5 [Organic compound (D)]

The organic compound (D) used in the present invention is optionally used to improve polymerization performance and properties of the obtainable polymers. Examples of such organic compounds include, but are not limited to, alcohols, phenolic compounds, carboxylic acids, phosphorus compounds and sulfonates.

[0080]

The organic compounds (D) may be used singly, or two or more kinds may be used in combination.

15 [0081]

In polymerization, the usage method and the order of addition of the above components are arbitrarily selected. Exemplary methods are given below.

(1) The transition metal compound (A) alone is added to a polymerization reactor.

(2) The transition metal compound (A) and the organometallic compound (B) are added to a polymerization reactor in any order.

(3) A catalyst component in which the transition metal

compound (A) is supported on the carrier (C), and the organometallic compound (B) are added to a polymerization reactor in any order.

(4) A catalyst component in which the organometallic compound (B) is supported on the carrier (C), and the transition metal compound (A) are added to a polymerization reactor in any order.

(5) A catalyst in which the transition metal compound (A) and the organometallic compound (B) are supported on the carrier (C) is added to a polymerization reactor.

[0082]

In the methods (1) to (5), the organic compound (D) may be added to a polymerization reactor in any order, or may be added to a polymerization reactor after contacted with at least one of the components (A) to (C). In the methods (2) to (5), two or more of the catalyst components may be contacted with one another beforehand.

[0083]

In the methods (4) and (5) in which the organometallic compound (B) is supported, an unsupported organometallic compound (B) may be added in any order as required. In this case, the organometallic compounds (B) may be the same as or different from each other.

[0084]

The solid catalyst component wherein the transition metal compound (A) alone is supported on the component (C), or the solid catalyst component wherein the transition metal compound (A) and the organometallic compound (B) are supported on the component (C) may be prepolymerized with an olefin. Further, an additional catalyst component may be supported on the prepolymerized solid catalyst component.

[0085]

In the olefin polymer production process according to the present invention, in the presence of the above olefin polymerization catalyst, an α -olefin having 3 to 10 carbon atoms and ethylene are polymerized to give an α -olefin polymer.

[0086]

< α -olefin>

Examples of α -olefins having 3 to 10 carbon atoms employable in the present invention include propylene, 1-butene, 1-pentene, 1-hexene, 1-heptene, 1-octene, 1-nonene, 1-decene, 3-methyl-1-butene, 3-methyl-1-pentene, 4-methyl-1-pentene, 3-ethyl-1-pentene, 4-methyl-1-hexene, 4,4-dimethyl-1-hexene, 4,4-dimethyl-1-pentene, 4-ethyl-1-hexene and 3-ethyl-1-hexene. Of these, the α -olefins having 3 to 8 carbon atoms are preferable; the α -olefins having 3 to 6 carbon atoms are more preferable; and propylene, 1-butene, 1-hexene and 4-methyl-1-pentene are particularly preferable.

[0087]

These α -olefins having 3 to 10 carbon atoms may be used singly, or two or more kinds may be used in combination. The α -olefins may be selected appropriately so that the obtainable
5 polymer will have desired properties. For example, the α -olefins may be selected appropriately so that the polymer and a mixture containing the polymer will have desired properties after vulcanization.

[0088]

10 <Production process of olefin polymer>

The present invention may be carried out by liquid-phase polymerization such as solution polymerization or suspension polymerization, or by gas-phase polymerization.

[0089]

15 Specific examples of an inert hydrocarbon medium (inert hydrocarbon solvent) used in the liquid-phase polymerization include aliphatic hydrocarbons such as propane, butane, pentane, hexane, heptane, octane, decane, dodecane, ethylene chloride, dichloromethane and kerosine; alicyclic hydrocarbons such as
20 cyclopentane, cyclohexane and methylcyclopentane; aromatic hydrocarbons such as benzene, toluene, chlorobenzene and xylene; and mixtures thereof. The α -olefin itself may be used as a solvent.

[0090]

In carrying out olefin polymerization using the olefin polymerization catalyst described above, the transition metal compound (A) is generally used such that the amount thereof per liter of the reaction volume is in the range of 10^{-9} to 10^{-1} mol, and preferably 10^{-8} to 10^{-2} mol.

[0091]

The organoaluminum oxy-compound (b-1) is used such that the molar ratio [(b-1)/M] relative to all the transition metal atoms (M) in the transition metal compound (A) is usually in the range of 0.01 to 50,000, preferably 0.05 to 2,000. The ionic compound (b-2) is used such that the molar ratio [(b-2)/M] of the ionic compound (b-2) to all the transition metal atoms (M) in the transition metal compound (A) is usually in the range of 0.01 to 50,000, preferably 0.05 to 2,000. The organoaluminum compound (b-3) is used such that the molar ratio [(b-3)/M] of the aluminum atoms in the organoaluminum compound (b-3) to all the transition metal atoms (M) in the transition metal compound (A) is usually in the range of 0.01 to 5,000, and preferably 0.05 to 2,000.

[0092]

The temperature of the olefin polymerization using such an olefin polymerization catalyst is usually in the range of +25 to +200°C, preferably +25 to +170°C, more preferably +30 to +150°C. The polymerization temperature, which varies

depending on the molecular weight of the obtainable α -olefin polymer and polymerization activity of the olefin polymerization catalyst, is preferably +30°C or higher in view of productivity.

5 [0093]

The polymerization pressure is usually from atmospheric pressure to 10 MPa gauge pressure, and preferably from atmospheric pressure to 5 MPa gauge pressure. The polymerization reaction may be carried out batchwise,
10 semi-continuously or continuously. The polymerization may be carried out in two or more stages under different reaction conditions.

[0094]

The molecular weight of the obtainable olefin polymers
15 may be controlled by use of hydrogen in the polymerization system or by adjusting the polymerization temperature. When hydrogen is added, the amount thereof is preferably about 0.001 to 100 NL based on 1 kg of the olefin. The molecular weight of the obtainable olefin polymers may be controlled also by
20 changing the amount of the component (B). At this time, specific examples of the component (B) include triisobutylaluminum, methylaluminoxane and diethyl zinc.

[0095]

The olefin polymer production process of the present

invention is characterized by limiting the ethylene feeding amount in the polymerization reaction system to be a specific amount. This is described as follows. When an α -olefin having 3 to 10 carbon atoms is fed as a gas, ethylene and the α -olefin having 3 to 10 carbon atoms each may be fed into a polymerization reactor continuously, or may be fed into a polymerization reactor intermittently. Provided that the molar amounts of ethylene and an α -olefin having 3 to 10 carbon atoms that are fed into a polymerization reactor are P_E and P_O , respectively, and when a whole amount of ethylene fed is assumed to be dissolved in a liquid in view of a slight ethylene-feeding amount, the present invention defines the molar ratio: P_E/P_O in the liquid. In this case, the present invention is characterized by satisfying the relationship: $0.001 \leq P_E/P_O \leq 0.030$. As long as the ratio is within this range, ethylene may be arbitrarily used. The ratio is preferably $0.001 \leq P_E/P_O \leq 0.020$, more preferably $0.001 \leq P_E/P_O \leq 0.010$, most preferably $0.001 \leq P_E/P_O \leq 0.005$.

[0096]

On the other hand, when an α -olefin having 3 to 10 carbon atoms is fed as a liquid, provided that the molar amounts of ethylene and an α -olefin having 3 to 10 carbon atoms that are fed into a polymerization reactor are P_E and P_O , respectively, and when ethylene fed is assumed to be dissolved in the α -olefin having 3 to 10 carbon atoms, the present invention defines the

molar ratio P_E/P_0 in the liquid. In this case, the present invention is characterized by satisfying the relationship: $0.001 \leq P_E/P_0 \leq 0.030$. As long as the ratio is within this range, ethylene may be arbitrarily used. The ratio is preferably $0.001 \leq P_E/P_0 \leq 0.020$, more preferably $0.001 \leq P_E/P_0 \leq 0.010$, most preferably $0.001 \leq P_E/P_0 \leq 0.005$.

[0097]

In the olefin polymer production process of the present invention, a trace amount of ethylene is polymerized to such a degree as to improve polymerization activity and allow the α -olefin polymer to have increased molecular weight. Thereby, a syndiotactic α -olefin polymer having high melting point can be produced. As mentioned above, in using metallocene catalysts for the polymerization of propylene, the presence of a dormant catalyst species with propylene 2,1-insertion is known; likewise, in the polymerization of α -olefins having 3 to 10 carbon atoms, too, the presence of a similar dormant catalyst species is presumable. Here, allowing ethylene in an amount defined above to make reaction is considered to be able to reactivate the dormant catalyst species to thereby improve the activity, and moreover prevent polymer chains from being eliminated from the catalyst species, thus enabling to resume the dormant growth reaction of the polymer chains and consequently allowing the α -olefin polymer to have increased

molecular weight. Surprisingly, it is characteristic that the increased effect is more significant in the production of the syndiotactic α -olefin polymer rather than in the production of the isotactic α -olefin polymer.

5 [0098]

<Olefin polymer>

Next, olefin polymers obtained by the production process of the present invention are described. The olefin polymers obtained by the production process of the present invention have
10 the following four characteristics.

[Characteristic 1] The olefin polymer comprises a structural unit X derived from at least one α -olefin selected from α -olefins having 3 to 10 carbon atoms and a structural unit Y derived from ethylene, and provided that the content of the
15 structural unit X in the polymer is x (mol%) and the content of the structural unit Y in the polymer is y (mol%), the polymer satisfies: $98.5 \leq x \leq 99.9$, $1.5 \geq y \geq 0.1$ and $x+y=100$; preferably $98.6 \leq x \leq 99.9$, $1.4 \geq y \geq 0.1$ and $x+y=100$; more preferably $98.7 \leq x \leq 99.9$, $1.3 \geq y \geq 0.1$ and $x+y=100$; most preferably $98.8 \leq x \leq 99.9$, $1.2 \geq y \geq 0.1$
20 and $x+y=100$. The olefin polymer produced by the production process of the present invention, in spite of containing a trace amount of the unit derived from ethylene, maintains high racemic diad fraction and high melting point, and has increased molecular weight. If the ethylene content y is more than the

range defined above, the olefin polymer has lowered melting point and moreover lowered crystallization temperature (T_c), and thus may have deteriorated molding processability.

[Characteristic 2] The racemic diad fraction ($[r]$) as
5 measured by ^{13}C -NMR is $90\% \leq [r] < 100\%$, preferably $95\% \leq [r] < 100\%$, more preferably $97\% \leq [r] < 100\%$, most preferably $98\% \leq [r] < 100\%$. The olefin polymer produced by the production process of the present invention has high racemic diad fraction, and therefore, the olefin polymer, in spite of containing a trace amount of
10 the unit derived from ethylene, maintains high melting point.

[Characteristic 3] The intrinsic viscosity ($[\eta]$) as measured at 135°C in decalin is 0.70 dl/g or more, preferably 0.75 dl/g or more, more preferably 0.80 dl/g or more, most preferably 0.85 dl/g or more. The olefin polymer having high
15 molecular weight is expected to show good strength and molding processability.

[Characteristic 4] The melting point (T_m) as determined by differential scanning calorimetry (DSC) is 145°C or higher, preferably $T_m \geq 147^\circ\text{C}$, more preferably $T_m \geq 149^\circ\text{C}$, most preferably
20 $T_m \geq 151^\circ\text{C}$. The olefin polymer produced by the production process of the present invention, in spite of containing a trace amount of the unit derived from ethylene, maintains high racemic diad fraction and high melting point, and has increased molecular weight.

[0099]

The olefin polymer of the present invention, in spite of containing a trace amount of the unit derived from ethylene, maintains high racemic diad fraction and high melting point,
5 and has high molecular weight.

This is considered to be due to the syndiotacticity of the α -olefin sequences. It is known that the syndiotacticity can adopt plural energetically-stabilized crystal structures including helical structure and planar zigzag structure and
10 reversible phase transition being possible between some of these crystal structures. In the case of the isotactic polypropylene, the structure is dominated by helical structure in which three molecules of propylene are present per turn of the helix, and thus, the inclusion into such structure of the
15 unit derived from ethylene even in a trace amount greatly affects the constituent crystal structure, and consequently the isotactic polypropylene tends to have a lowered melting point. On the other hand, in the case of the syndiotactic polypropylene, the influence of the unit derived from ethylene on the crystal
20 structure is presumed to be minimized by the plural energetically-stabilized crystal structures, and consequently the syndiotactic polypropylene hardly has a lowered melting point. Since similar effect is seen also in a syndiotactic α -olefin polymer other than the syndiotactic propylene, this

phenomenon is considered to be characteristic to the syndiotactic structure.

Examples

5 [0100]

Hereinafter, the present invention is described more specifically with reference to examples, but the present invention is in no way limited by these examples. First of all, methods for measuring properties of the olefin polymers
10 obtained by the production process of the present invention are described.

[0101]

<Intrinsic viscosity [η] >

The intrinsic viscosity is a value measured at 135°C in
15 decalin.

[0102]

<Melting point (T_m), Crystallization temperature (T_c), Amount of heat of fusion ($\Delta H(T_m)$)>

With regard to a 4-methyl-1-pentene polymer, the
20 following operation was performed. A differential scanning calorimeter manufactured by SII NanoTechnology Inc.: EXSTAR 6000DSC was employed. Under the stream of nitrogen (20 mL/min), the specimen (about 5 mg) was heated to 270°C at 10°C/min and was held at 270°C for 5 minutes, and then the specimen was cooled

to 0°C at -10°C/min and was held at 0°C for 5 minutes, and heated to 270°C at 10°C/min. At this time, a top of a crystallization temperature peak at the time of cooling was defined as a crystallization temperature (T_c). A top of a crystal melting peak at the time of the second heating was defined as a melting point (T_m). From an integrated value of the peak, an amount of heat of fusion ($\Delta H(T_m)$) was calculated.

[0103]

With regard to a propylene polymer, the following operation was performed. A differential scanning calorimeter manufactured by SII NanoTechnology Inc.: EXSTAR 6000DSC was employed. Under the stream of nitrogen (20 mL/min), the specimen (about 5 mg) was heated to 230°C at 10°C/min and was held at 230°C for 10 minutes, and then the specimen was cooled to 30°C at -10°C/min and was held at 30°C for 5 minutes, and heated to 230°C at 10°C/min. At this time, a top of a crystallization temperature peak at the time of cooling was defined as a crystallization temperature (T_c). A top of a crystal melting peak at the time of the second heating was defined as a melting point (T_m). From an integrated value of the peak, an amount of heat of fusion ($\Delta H(T_m)$) was calculated.

[0104]

With regard to an olefin polymer obtained in Examples and Comparative Examples, when two or more crystal melting peaks

were observed, a top of a peak at the highest melting point side was defined as a melting point (T_m) of the olefin polymer.

[0105]

<Stereoregularity and Ethylene content>

5 As a measurement solvent,
o-dichlorobenzene- d_4 /benzene- d_6 (4/1 [v/v]) and
1,1,2,2-tetrachloroethane- d_2 were used. At a measurement
temperature of 120°C, ^{13}C -NMR spectrum (125 MHz, ECP500
manufactured by JOEL Ltd., and 100 MHz, ECX400P manufactured
10 by JOEL Ltd.) was measured to calculate a racemic diad fraction
($[r]$) of an olefin polymer. The calculation was performed
neglecting the influence of ethylene insertion. For example,
the racemic diad fraction ($[r]$) of a polymer containing
4-methyl-1-pentene as a main component was calculated by
15 defining an integral value of a signal derived from a racemic
structure (approximately at 42.7 ppm) as "A" and an integral
value of a signal derived from a meso structure (approximately
at 42.4 ppm) as "B", and on the basis of the meso diad fraction
($[m]$)/the racemic diad fraction ($[r]$) = B/A and $[m] + [r] = 100$.
20 The racemic diad fraction ($[r]$) of a polymer containing
propylene as a main component can be calculated with reference
to publicly known documents. On the other hand, the ethylene
content was determined by ^{13}C -NMR spectrum, with reference to
(Macromolecules, 1982, 15, 1150).

[0106]

<Molar ratio>

Among α -olefins having 3 to 10 carbon atoms, as an example of a gas, propylene is described, and as an example of a liquid,
 5 4-methyl-1-pentene is described. As described above, in the case of propylene, when the molar amount of ethylene fed was defined as M_E and the molar amount of propylene fed was defined as M_O , the molar ratio M_E/M_O (ethylene flow rate/propylene flow rate) was calculated. In the case of 4-methyl-1-pentene, when
 10 the molar amount of ethylene fed was defined as P_E and the molar amount of 4-methyl-1-pentene fed was defined as P_O , the molar ratio of P_E/P_O (ethylene flow rate/4-methyl-1-pentene introducing amount) was calculated.

[0107]

15 <Transition metal compound (A)>

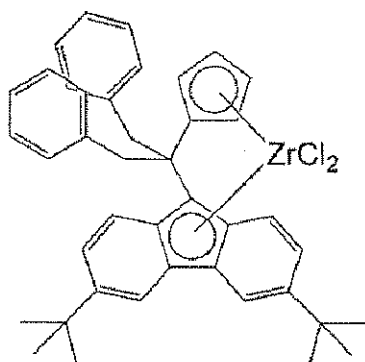
The transition metal compound (A) was synthesized by methods described in the following Patent Literatures:
 JP-A-2000-212194, JP-A-2004-168744, JP-A-2004-189666,
 JP-A-2004-161957, JP-A-2007-302854, JP-A-2007-302853,
 20 WO01/027124, JP-A-2001-526730 and JP-A-H10-226694.

[0108]

Transition metal compound (a1):

dibenzylmethylene(cyclopentadienyl)(3,6-di-tert-butylfluorenyl)zirconiumdichloride

[0109]

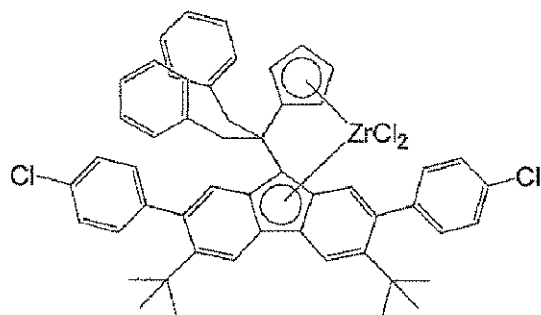


[0110]

Transition metal compound (a2):

- 5 dibenzylmethylene(cyclopentadienyl) (2,7-di-p-chlorophenyl-3,6-di-tert-butylfluorenyl) zirconiumdichloride

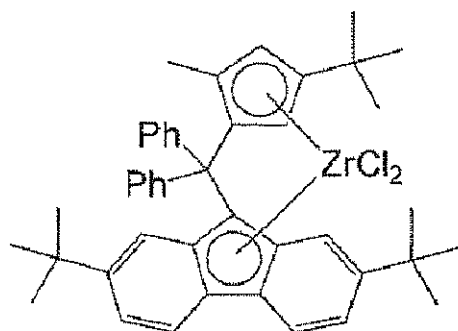
[0111]



[0112]

- 10 Transition metal compound (a3):
diphenylmethylene(3-tert-butyl-5-methylcyclopentadienyl) (2,7-di-tert-butylfluorenyl) zirconiumdichloride

[0113]

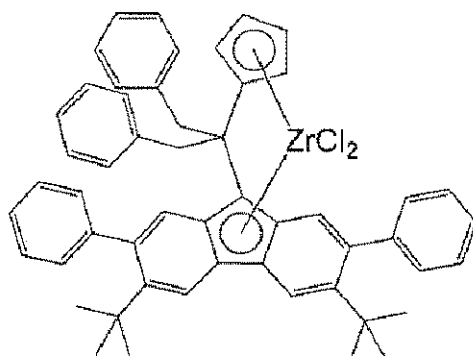


[0114]

Transition metal compound (a4):

dibenzylmethylene(cyclopentadienyl) (2,7-diphenyl-3,6-di-ter
5 t-butylfluorenyl) zirconiumdichloride

[0115]

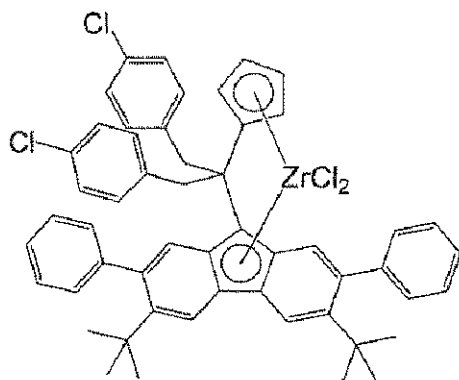


[0116]

Transition metal compound (a5):

10 di-p-chlorobenzylmethylene(cyclopentadienyl) (2,7-diphenyl-3
,6-di-tert-butylfluorenyl) zirconiumdichloride

[0117]



[0118]

[Example 1]

[Production of 4-methyl-1-pentene polymer]

5 Into a sufficiently nitrogen-purged 500 mL glass autoclave (equipped with a glass blowing tube), 200 mL of 4-methyl-1-pentene was introduced and was kept at 30°C. On the other hand, into a sufficiently nitrogen-purged 30 mL side-arm flask, a magnetic stirrer was placed, and thereto, 1.31 mL (Al=

10 2 mmol) of a hexane solution of methylaluminoxane (Al concentration: 1.52 mol/L) manufactured by Tosoh Finechem Corporation, and then 2.79 mg (0.004 mmol) of dibenzylmethylene(cyclopentadienyl)(3,6-di-tert-butylfluorenyl)zirconiumdichloride and 2 mL of dehydrated toluene were

15 added and were stirred for 10 minutes. Into the autoclave to which nitrogen had been flown, 1.0 mmol of a toluene solution of triisobutylaluminum (Al= 1.0 M) was added, and then the above solution was added to the autoclave. Through the glass blowing tube, a mixed gas of 2.5 NL/h of nitrogen and 0.5 NL/h of ethylene

was flown to initiate polymerization. In the polymerization atmosphere: P_O was 1.5875 and P_E was 0.0037, and thus P_E/P_O was calculated to be 0.0023. The mixed gas of nitrogen and ethylene was continuously fed during polymerization and under ordinary pressure at 30°C for 10 minutes, polymerization was performed. Thereafter, a small amount of isobutylalcohol was added to terminate polymerization. The polymer solution was added to 1.5 L of methanol containing 1 mL of hydrochloric acid, to precipitate a 4-methyl-1-pentene polymer. The polymer was vacuum dried at 80°C for 10 hours: as a result, 4.90 g of the 4-methyl-1-pentene polymer was obtained. The polymerization activity was 7.35 kg/mmol-Zr·hr. With regard to the 4-methyl-1-pentene polymer obtained: $[\eta]$ was 0.88 dl/g, T_c was 153°C, T_m was 201°C, $\Delta H(T_m)$ was 14.2 mJ/mg, ethylene content was 0.2%, and $[r]$ was 98.2%.

[0119]

[Example 2]

[Production of 4-methyl-1-pentene polymer]

Into a sufficiently nitrogen-purged 500 mL glass autoclave (equipped with a glass blowing tube), 200 mL of 4-methyl-1-pentene was introduced and was kept at 30°C. On the other hand, into a sufficiently nitrogen-purged 30 mL side-arm flask, a magnetic stirrer was placed, and thereto, 1.31 mL (Al = 2 mmol) of a hexane solution of methylaluminoxane (Al

concentration: 1.52 mol/L) manufactured by Tosoh Finechem Corporation, and then 2.79 mg (0.004 mmol) of dibenzylmethylene(cyclopentadienyl)(3,6-di-tert-butylfluorenyl)zirconiumdichloride and 2 mL of dehydrated toluene were added and were stirred for 10 minutes. Into the autoclave to which nitrogen had been flown, 1.0 mmol of a toluene solution of triisobutylaluminum (Al= 1.0 M) was added, and then the above solution was added to the autoclave. Through the glass blowing tube, a mixed gas of 10 NL/h of nitrogen and 2 NL/h of ethylene was flown to initiate polymerization. In the polymerization atmosphere: P_0 was 1.5875 and P_E was 0.0074, and thus P_E/P_0 was calculated to be 0.0047. The mixed gas of nitrogen and ethylene was continuously fed during polymerization and under ordinary pressure at 30°C for 5 minutes, polymerization was performed. Thereafter, a small amount of isobutylalcohol was added to terminate polymerization. The polymer solution was added to 1.5 L of methanol containing 1 mL of hydrochloric acid, to precipitate a 4-methyl-1-pentene polymer. The polymer was vacuum dried at 80°C for 10 hours: as a result, 2.59 g of the 4-methyl-1-pentene polymer was obtained. The polymerization activity was 7.77 kg/mmol-Zr·hr. With regard to the 4-methyl-1-pentene polymer obtained, the intrinsic viscosity $[\eta]$ was 0.98 dl/g, T_c was 149°C, T_m was 199°C, $\Delta H(T_m)$ was 15.1 mJ/mg, ethylene content was 0.4%, and $[r]$ was 97.7%.

[0120]

[Example 3]

[Production of 4-methyl-1-pentene polymer]

Into a sufficiently nitrogen-purged 500 mL glass
5 autoclave (equipped with a glass blowing tube), 200 mL of
4-methyl-1-pentene was introduced and was kept at 30°C. On the
other hand, into a sufficiently nitrogen-purged 30 mL side-arm
flask, a magnetic stirrer was placed, and thereto, 1.31 mL (Al=
2 mmol) of a hexane solution of methylaluminoxane (Al
10 concentration: 1.52 mol/L) manufactured by Tosoh Finechem
Corporation, and then 2.79 mg (0.004 mmol) of
dibenzylmethylene(cyclopentadienyl) (3,6-di-tert-butylfluore
nyl)zirconiumdichloride and 2 mL of dehydrated toluene were
added and were stirred for 10 minutes. Into the autoclave to
15 which nitrogen had been flown, 1.0 mmol of a toluene solution
of triisobutylaluminum (Al= 1.0 M) was added, and then the above
solution was added to the autoclave. Through the glass blowing
tube, a mixed gas of 10 NL/h of nitrogen and 6 NL/h of ethylene
was flown to initiate polymerization. In the polymerization
20 atmosphere: P_0 was 1.5875 and P_E was 0.0223, and thus P_E/P_0 was
calculated to be 0.0141. The mixed gas of nitrogen and ethylene
was continuously fed during polymerization and under ordinary
pressure at 30°C for 5 minutes, polymerization was performed.
Thereafter, a small amount of isobutylalcohol was added to

terminate polymerization. The polymer solution was added to 1.5 L of methanol containing 1 mL of hydrochloric acid, to precipitate a 4-methyl-1-pentene polymer. The polymer was vacuum dried at 80°C for 10 hours: as a result, 2.96 g of the 4-methyl-1-pentene polymer was obtained. The polymerization activity was 8.88 kg/mmol-Zr·hr. With regard to the 4-methyl-1-pentene polymer obtained: the intrinsic viscosity $[\eta]$ was 1.10 dl/g, T_c was 143°C, T_m was 197°C, $\Delta H(T_m)$ was 13.7 mJ/mg, ethylene content was 0.6%, and $[r]$ was 97.6%.

10 [0121]

[Example 4]

[Production of 4-methyl-1-pentene polymer]

Into a sufficiently nitrogen-purged 500 mL glass autoclave (equipped with a glass blowing tube), 200 mL of 4-methyl-1-pentene was introduced and was kept at 30°C. On the other hand, into a sufficiently nitrogen-purged 30 mL side-arm flask, a magnetic stirrer was placed, and thereto, 1.31 mL (Al= 2 mmol) of a hexane solution of methylaluminoxane (Al concentration: 1.52 mol/L) manufactured by Tosoh Finechem Corporation, and then 2.79 mg (0.004 mmol) of dibenzylmethylene(cyclopentadienyl)(3,6-di-tert-butylfluorenyl)zirconiumdichloride and 2 mL of dehydrated toluene were added and were stirred for 10 minutes. Into the autoclave to which nitrogen had been flown, 1.0 mmol of a toluene solution

of triisobutylaluminum ($Al = 1.0\text{ M}$) was added, and then the above solution was added to the autoclave. Through the glass blowing tube, a mixed gas of 10 NL/h of nitrogen and 10 NL/h of ethylene was flown to initiate polymerization. In the polymerization atmosphere: P_0 was 1.5875 and P_E =molar amount of ethylene was 0.0372, and thus P_E/P_0 was calculated to be 0.0234. The mixed gas of nitrogen and ethylene was continuously fed during polymerization and under ordinary pressure at 30°C for 5 minutes, polymerization was performed. Thereafter, a small amount of isobutylalcohol was added to terminate polymerization. The polymer solution was added to 1.5 L of methanol containing 1 mL of hydrochloric acid, to precipitate a 4-methyl-1-pentene polymer. The polymer was vacuum dried at 80°C for 10 hours: as a result, 3.18 g of the 4-methyl-1-pentene polymer was obtained. The polymerization activity was $9.54\text{ kg}/\text{mmol-Zr}\cdot\text{hr}$. With regard to the 4-methyl-1-pentene polymer obtained: the intrinsic viscosity $[\eta]$ was 1.18 dl/g , T_c was 139°C , T_m was 195°C , $\Delta H(T_m)$ was 12.7 mJ/mg , ethylene content was 1.0%, and $[r]$ was 97.9%.

[0122]

[Comparative Example 1]

[Production of 4-methyl-1-pentene polymer]

Into a sufficiently nitrogen-purged 500 mL glass autoclave (equipped with a glass blowing tube), 200 mL of

4-methyl-1-pentene was introduced and was kept at 30°C. On the other hand, into a sufficiently nitrogen-purged 30 mL side-arm flask, a magnetic stirrer was placed, and thereto, 1.31 mL (Al= 2 mmol) of a hexane solution of methylaluminoxane (Al concentration: 1.52 mol/L) manufactured by Tosoh Finechem Corporation, and then 2.79 mg (0.004 mmol) of dibenzylmethylene(cyclopentadienyl)(3,6-di-tert-butylfluorenyl)zirconiumdichloride and 2 mL of dehydrated toluene were added and were stirred for 10 minutes. Into the autoclave to which nitrogen had been flown, 1.0 mmol of a toluene solution of triisobutylaluminum (Al= 1.0 M) was added, and then the above solution was added to the autoclave. Through the glass blowing tube, 50 NL/h of nitrogen was flown to initiate polymerization. Nitrogen was continuously fed during polymerization and under ordinary pressure at 30°C for 30 minutes, polymerization was performed. Thereafter, a small amount of isobutylalcohol was added to terminate polymerization. The polymer solution was added to 1.5 L of methanol containing 1 mL of hydrochloric acid, to precipitate a 4-methyl-1-pentene polymer. The polymer was vacuum dried at 80°C for 10 hours: as a result, 0.43 g of the 4-methyl-1-pentene polymer was obtained. The polymerization activity was 0.22 kg/mmol-Zr·hr. With regard to the 4-methyl-1-pentene polymer obtained: the intrinsic viscosity $[\eta]$ was 0.60 dl/g, T_c was 155°C, T_m was 204°C, $\Delta H(T_m)$ was 20.3

mJ/mg, ethylene content was 0.0%, and $[\eta]$ was 98.0%.

[0123]

[Comparative Example 2]

[Production of 4-methyl-1-pentene polymer]

5 The experiment was performed in the same manner as in Example 1, except that through the glass blowing tube, a mixed gas of 10 NL/h of nitrogen and 100 NL/h of ethylene was flown and in the polymerization atmosphere, P_E/P_0 was 0.2340.

[0124]

10 [Comparative Example 3]

[Production of 4-methyl-1-pentene polymer]

 The experiment was performed in the same manner as in Example 1, except that through the glass blowing tube, a mixed gas containing 150 NL/h of ethylene was flown and in the
15 polymerization atmosphere, P_E/P_0 was 0.2808.

[0125]

[Example 5]

[Production of propylene polymer]

 Into a sufficiently nitrogen-purged 500 mL glass
20 autoclave (equipped with a glass blowing tube), 400 mL of heptane was introduced and was kept at 50°C. On the other hand, into a sufficiently nitrogen-purged 30 mL side-arm flask, a magnetic stirrer was placed, and thereto, 2.62 mL (Al= 4 mmol) of a hexane solution of methylaluminoxane (Al concentration:

1.52 mol/L) manufactured by Tosoh Finechem Corporation, and then 3.67 mg (0.004 mmol) of dibenzylmethylene(cyclopentadienyl)(2,7-di-p-chlorophenyl-3,6-di-tert-butylfluorenyl)zirconiumdichloride and 2 mL of dehydrated toluene were added and were stirred for 10 minutes. Into the autoclave to which nitrogen had been flown, 1.0 mmol of a toluene solution of triisobutylaluminum (Al= 1.0 M) was added, and then the above solution was added to the autoclave. Through the glass blowing tube, a mixed gas of 150 NL/h of propylene and 1 NL/h of ethylene was flown to initiate polymerization. In the polymerization atmosphere, P_E/P_0 was calculated to be 0.0067. The mixed gas of propylene and ethylene was continuously fed during polymerization and under ordinary pressure at 50°C for 15 minutes, polymerization was performed. Thereafter, a small amount of isobutylalcohol was added to terminate polymerization. The polymer solution was added to 1.5 L of methanol containing 1 mL of hydrochloric acid, to precipitate a propylene polymer. The propylene polymer obtained was vacuum dried at 80°C for 10 hours: as a result, 3.76 g of the propylene polymer was obtained. The polymerization activity was 3.76 kg/mmol-Zr·hr. With regard to the propylene polymer: $[\eta]$ was 1.57 dl/g, T_c was 102°C, T_m was 155°C, $\Delta H(T_m)$ was 51.6 mJ/mg, ethylene content was 0.5%, $[r]$ was 98.0%.

[0126]

[Example 6]

[Production of propylene polymer]

The experiment was performed in the same manner as in
5 Example 5, except that through the glass blowing tube, a mixed
gas of 150 NL/h of propylene and 0.8 NL/h of ethylene was flown
to initiate polymerization and in the polymerization atmosphere,
 P_E/P_O was 0.0053.

[0127]

10 [Example 7]

[Production of propylene polymer]

The experiment was performed in the same manner as in
Example 5, except that through the glass blowing tube, a mixed
gas of 150 NL/h of propylene and 1.5 NL/h of ethylene was flown
15 to initiate polymerization and in the polymerization atmosphere,
 P_E/P_O was 0.0100.

[0128]

[Example 8]

[Production of propylene polymer]

20 The experiment was performed in the same manner as in
Example 5, except that through the glass blowing tube, a mixed
gas of 150 NL/h of propylene and 4.0 NL/h of ethylene was flown
to initiate polymerization and in the polymerization atmosphere,
 P_E/P_O was 0.0267.

[0129]

[Comparative Example 4]

[Production of propylene polymer]

The experiment was performed in the same manner as in
5 Example 5, except that through the glass blowing tube, 150 NL/h
of propylene alone was flown to initiate polymerization.

[0130]

[Comparative Example 5]

[Production of propylene polymer]

10 The experiment was performed in the same manner as in
Example 5, except that through the glass blowing tube, a mixed
gas of 150 NL/h of propylene and 10.5 NL/h of ethylene was flown
to initiate polymerization and in the polymerization atmosphere,
 P_E/P_0 was 0.0700.

15 [0131]

[Example 9]

[Production of propylene polymer]

The experiment was performed in the same manner as in
Example 5, except that the transition metal compound was (a4):
20 dibenzylmethylene(cyclopentadienyl) (2,7-diphenyl-3,6-di-ter
t-butylfluorenyl)zirconiumdichloride, and through the glass
blowing tube, a mixed gas of 150 NL/h of propylene and 0.3 NL/h
of ethylene was flown to initiate polymerization and in the
polymerization atmosphere, P_E/P_0 was 0.0020.

[0132]

[Example 10]

[Production of propylene polymer]

The experiment was performed in the same manner as in
5 Example 5, except that the transition metal compound was (a4):
dibenzylmethylene(cyclopentadienyl)(2,7-diphenyl-3,6-di-ter
t-butylfluorenyl)zirconiumdichloride.

[0133]

[Comparative Example 6]

10 [Production of propylene polymer]

The experiment was performed in the same manner as in
Example 5, except that the transition metal compound was (a4):
dibenzylmethylene(cyclopentadienyl)(2,7-diphenyl-3,6-di-ter
t-butylfluorenyl)zirconiumdichloride, and through the glass
15 blowing tube, 150 NL/h of propylene alone was flown to initiate
polymerization.

[0134]

[Example 11]

[Production of propylene polymer]

20 The experiment was performed in the same manner as in
Example 5, except that the transition metal compound was (a5):
di-p-chlorobenzylmethylene(cyclopentadienyl)(2,7-diphenyl-3
,6-di-tert-butylfluorenyl)zirconiumdichloride, and through
the glass blowing tube, a mixed gas of 150 NL/h of propylene

and 0.45 NL/h of ethylene was flown to initiate polymerization and in the polymerization atmosphere, P_E/P_0 was 0.0033.

[0135]

[Comparative Example 7]

5 [Production of propylene polymer]

The experiment was performed in the same manner as in Example 5, except that the transition metal compound was (a5): di-p-chlorobenzylmethylene(cyclopentadienyl)(2,7-diphenyl-3,6-di-tert-butylfluorenyl)zirconiumdichloride, and through
10 the glass blowing tube, 150 NL/h of propylene alone was flown to initiate polymerization.

[0136]

[Reference Example 1]

[Production of 4-methyl-1-pentene polymer]

15 Into a sufficiently nitrogen-purged 500 mL glass autoclave (equipped with a glass blowing tube), 200 mL of 4-methyl-1-pentene was introduced and was kept at 40°C. On the other hand, into a sufficiently nitrogen-purged 30 mL side-arm flask, a magnetic stirrer was placed, and thereto, 1.31 mL (Al
20 = 2 mmol) of a hexane solution of methylaluminoxane (Al concentration: 1.52 mol/L) manufactured by Tosoh Finechem Corporation, and then 2.96 mg (0.004 mmol) of diphenylmethylene(3-tert-butyl-5-methylcyclopentadienyl)(2,7-di-tert-butylfluorenyl)zirconiumdichloride and 2 mL of

dehydrated toluene were added and were stirred for 10 minutes. Into the autoclave to which nitrogen had been flown, 1.0 mmol of a toluene solution of triisobutylaluminum (Al= 1.0 M) was added, and then the above solution was added to the autoclave.

5 Through the glass blowing tube, 25 NL/h of nitrogen was flown to initiate polymerization. Nitrogen was continuously fed during polymerization and under ordinary pressure at 40°C for 30 minutes, polymerization was performed. Thereafter, a small amount of isobutylalcohol was added to terminate polymerization.

10 The polymer solution was added to 1.5 L of methanol containing 1 mL of hydrochloric acid, to precipitate a 4-methyl-1-pentene polymer. The polymer was vacuum dried at 80°C for 10 hours: as a result, 1.82 g of the 4-methyl-1-pentene polymer was obtained. The polymerization activity was 0.91 kg/mmol-Zr·hr.

15 With regard to the 4-methyl-1-pentene polymer obtained, the intrinsic viscosity[η] was 2.04 dl/g, T_c was 203°C, T_m was 232°C, $\Delta H(T_m)$ was 27.8 mJ/mg, ethylene content was 0.0%, and [r] was 2.0%.

[0137]

20 [Reference Example 2]

Into a sufficiently nitrogen-purged 500 mL glass autoclave (equipped with a glass blowing tube), 200 mL of 4-methyl-1-pentene was introduced and was kept at 40°C. On the other hand, into a sufficiently nitrogen-purged 30 mL side-arm

flask, a magnetic stirrer was placed, and thereto, 1.31 mL (Al = 2 mmol) of a hexane solution of methylaluminoxane (Al concentration: 1.52 mol/L) manufactured by Tosoh Finechem Corporation, and then 2.96 mg (0.004 mmol) of

5 diphenylmethylene(3-tert-butyl-5-methylcyclopentadienyl)(2, 7-di-tert-butylfluorenyl)zirconiumdichloride and 2 mL of dehydrated toluene were added and were stirred for 10 minutes. Into the autoclave to which nitrogen had been flown, 1.0 mmol of a toluene solution of triisobutylaluminum (Al= 1.0 M) was

10 added, and then the above solution was added to the autoclave. Through the glass blowing tube, a mixed gas of 100 NL/h of nitrogen and 20 NL/h of ethylene was flown to initiate polymerization. In the polymerization atmosphere: P_0 was 1.5875 and P_E was 0.1488, and thus P_E/P_0 was calculated to be

15 0.0937. The mixed gas of nitrogen and ethylene was continuously fed during polymerization and under ordinary pressure at 40°C for 10 minutes, polymerization was performed. Thereafter, a small amount of isobutylalcohol was added to terminate polymerization. The polymer solution was added to 1.5 L of

20 methanol containing 1 mL of hydrochloric acid, to precipitate a 4-methyl-1-pentene polymer. The polymer was vacuum dried at 80°C for 10 hours: as a result, 1.03 g of the 4-methyl-1-pentene polymer was obtained. The polymerization activity was 1.55 kg/mmol-Zr·hr. With regard to the 4-methyl-1-pentene polymer

obtained: $[\eta]$ was 1.57 dl/g, T_c was 200°C, T_m was 228°C, $\Delta H(T_m)$ was 19.2 mJ/mg, ethylene content was 0.3%, and $[r]$ was 2.0%.

[0138]

[Reference Example 3]

5 The experiment was performed in the same manner as in Reference Example 2, except that through the glass blowing tube, a mixed gas of 25 NL/h of nitrogen and 0.5 NL/h of ethylene was flown to initiate polymerization and in the polymerization atmosphere, P_E/P_0 was 0.0023.

10 [0139]

[Reference Example 4]

 The experiment was performed in the same manner as in Reference Example 2, except that through the glass blowing tube, a mixed gas of 20 NL/h of nitrogen and 4 NL/h of ethylene was
15 flown to initiate polymerization and in the polymerization atmosphere, P_E/P_0 was 0.0190.

[0140]

 The results of Examples 1 to 11, Comparative Examples 1 to 7 and Reference Examples 1 to 4 are set forth in Tables 1-1
20 to 1-5.

[0141]

[Table 1-1]

Table 1-1

Run-No.	α -olefin	Transition metal compound	P_E/P_0	Polymerization activity kg/mmol-Zr·hr	$[\eta]$ dl/g	Tc °C	Tm °C	Ethylene content mol%	$[\eta]$ %
Ex.1	4-methyl-1-pentene	al	0.0023	7.35	0.88	153	201	0.2	98.2
Ex.2	4-methyl-1-pentene	al	0.0047	7.77	0.98	149	199	0.4	97.7
Ex.3	4-methyl-1-pentene	al	0.0141	8.88	1.10	143	197	0.6	97.6
Ex.4	4-methyl-1-pentene	al	0.0234	9.54	1.18	139	195	1.0	97.9
Comp.Ex.1	4-methyl-1-pentene	al	0.0000	0.22	0.60	155	204	0.0	98.0
Comp.Ex.2	4-methyl-1-pentene	al	0.2340	17.30	1.22	118	181	3.6	97.7
Comp.Ex.3	4-methyl-1-pentene	al	0.2808	16.69	1.37	109	172	4.5	97.7

[0142]

Table 1-2

Run-No.	α -olefin	Transition metal compound	P_E/P_0	Polymerization activity kg/mmol-Zr·hr	$[\eta]$ dl/g	Tc °C	Tm °C	Ethylene content mol%	$[\eta]$ %
Ex. 5	propylene	a2	0.0067	3.76	1.57	102	155	0.5	98.0
Ex. 6	propylene	a2	0.0053	3.05	1.49	104	155	0.3	98.7
Ex. 7	propylene	a2	0.0100	3.50	1.50	103	154	0.5	98.0
Ex. 8	propylene	a2	0.0267	3.83	1.52	101	153	1.2	97.8
Comp.Ex. 4	propylene	a2	0.0000	1.60	1.40	102	156	0.0	98.0
Comp.Ex. 5	propylene	a2	0.0700	5.95	1.40	87	140	3.0	97.0

[0143]

Table 1-3

Run-No.	α -olefin	Transition metal compound	P_E/P_0	Polymerization activity kg/mmol-Zr·hr	$[\eta]$ dl/g	Tc °C	Tm °C	Ethylene content mol%	$[\alpha]$ °
Ex. 9	propylene	a4	0.0020	5.80	1.73	101	154	0.5	98.0
Ex. 10	propylene	a4	0.0067	8.60	1.84	99	152	1.4	96.0
Comp. Ex. 6	propylene	a4	0.0000	2.69	1.72	103	154	0.0	98.0

[0144]

Table 1-4

Run-No.	α -olefin	Transition metal compound	P_E/P_0	Polymerization activity kg/mmol-Zr·hr	$[\eta]$ dl/g	Tc °C	Tm °C	Ethylene content mol%	[r] %
Ex.11	propylene	a5	0.0033	4.17	1.65	145	152	0.7	97.5
Comp.Ex.7	propylene	a5	0.0000	2.03	1.55	145	156	0.0	98.0

Table 1-5

Run-No.	α -olefin	Transition metal compound	P_E/P_0	Polymerization activity Kg/mmole-Zr·hr	$[\eta]$ dl/g	T_c °C	T_m °C	Ethylene content mol%	$[r]$ %
Ref.Ex.1	4-methyl-1-pentene	a3	0.0000	0.91	2.04	203	232	0.0	2.0
Ref.Ex.2	4-methyl-1-pentene	a3	0.0937	1.55	1.57	200	228	0.3	2.0
Ref.Ex.3	4-methyl-1-pentene	a3	0.0023	1.68	1.66	203	231	0.0	2.0
Ref.Ex.4	4-methyl-1-pentene	a3	0.0190	1.95	1.76	205	231	0.0	2.0

5 Transition metal compounds

(a1): dibenzylmethylene(cyclopentadienyl)(3,6-di-tert-butylfluorenyl)zirconiumdichloride

(a2): dibenzylmethylene(cyclopentadienyl)(2,7-di-p-chlorophenyl-3,6-di-tert-butylfluorenyl)zirconiumdichloride

(a3): diphenylmethylene(3-tert-butyl-5-methylcyclopentadienyl)(2,7-di-tert-butylfluorenyl)zirconiumdichloride

(a4): dibenzylmethylene(cyclopentadienyl)(2,7-diphenyl-3,6-di-tert-butylfluorenyl)zirconiumdichloride

(a5): di-p-chlorobenzylmethylene(cyclopentadienyl)(2,7-diphenyl-3,6-di-tert-butylfluorenyl)zirconiumdichloride

Industrial Applicability

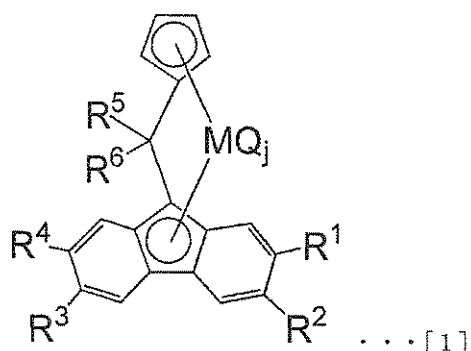
[0146]

The production of syndiotactic α -olefin polymers having
5 high molecular weight and high melting point with excellent
polymerization activity under industrially-possible
production conditions that is accomplished by the present
invention brings great advantage to polyolefin industry. For
example, when propylene and ethylene are used as a monomer, the
10 resultant syndiotactic polypropylene, in spite of containing
a trace amount of a unit derived from ethylene, has high racemic
diad fraction and high molecular weight and maintains high
melting point; furthermore, when α -olefins other than propylene
are used, too, syndiotactic α -olefin polymers having high
15 racemic diad fraction and high molecular weight and maintaining
high melting point can be industrially produced. In this way,
the present invention finds a wide range of applications and
thus is useful.

CLAIMS

1. A process for producing a syndiotactic α -olefin polymer comprising polymerizing a monomer that comprises at least one α -olefin having 3 to 10 carbon atoms and a small amount of ethylene, in the presence of an olefin polymerization catalyst comprising a transition metal compound (A) represented by the following general formula [1], at least one compound (B) selected from an organoaluminum oxy-compound (b-1), a compound (b-2) that reacts with the transition metal compound (A) to form an ion pair and an organoaluminum compound (b-3),

which process for producing a syndiotactic α -olefin polymer satisfies the relationship: $0.001 \leq P_E/P_0 \leq 0.030$, provided that the molar amounts of ethylene and an α -olefin having 3 to 10 carbon atoms that are fed into a polymerization reactor under a polymerization temperature of not lower than 25°C are P_E and P_0 , respectively;



wherein four groups: R^1 , R^2 , R^3 and R^4 are selected from the group consisting of a hydrogen atom, a hydrocarbon group

and a silicon-containing group, and may be the same as or different from one another; R^1 and R^2 are not bonded to each other to form a ring; R^3 and R^4 are not bonded to each other to form a ring; R^5 and R^6 are each an atom or a substituent selected
5 from the group consisting of a hydrogen atom, a hydrocarbon group having 2 to 20 carbon atoms and a silicon-containing group, and may be the same as or different from one another; M is selected from a titanium atom, a zirconium atom and a hafnium atom; Q is a halogen atom, a hydrocarbon group, a neutral and
10 conjugated or non-conjugated diene having 10 or less carbon atoms, an anionic ligand or a neutral ligand capable of coordination by lone pair electrons; j is an integer of 1 to 4, and when j is 2 or more, the plurality of Q may be the same as or different from one another.

15

2. The process for producing a syndiotactic α -olefin polymer according to claim 1, wherein in the general formula [1], R^2 and R^3 are the same atom or the same group.

20

3. The process for producing a syndiotactic α -olefin polymer according to claim 1 or 2, wherein in the general formula [1], R^2 and R^3 are t-butyl groups.

4. The process for producing a syndiotactic α -olefin

polymer according to any one of claims 1 to 3, wherein in the general formula [1], R^2 and R^3 are t-butyl groups; and R^1 and R^4 are hydrogen atoms or aryl groups having 6 to 20 carbon atoms and may be the same as or different from each other.

5

5. The process for producing a syndiotactic α -olefin polymer according to claim 1, wherein in the general formula [1], R^5 and R^6 are hydrocarbon groups having 6 to 20 carbon atoms and may be the same as or different from each other.

10

6. The process for producing a syndiotactic α -olefin polymer according to claim 1 or 5, wherein in the general formula [1], R^5 and R^6 are aryl groups having 6 to 20 carbon atoms or aralkyl groups having 6 to 20 carbon atoms, and may be the same
15 as or different from each other.

7. The process for producing a syndiotactic α -olefin polymer according to any one of claims 1 to 6, wherein in the general formula [1], R^2 and R^3 are t-butyl groups; R^1 and R^4 are
20 hydrogen atoms or aryl groups having 6 to 20 carbon atoms and may be the same as or different from each other; and R^5 and R^6 are aryl groups having 6 to 20 carbon atoms or aralkyl groups having 6 to 20 carbon atoms, and may be the same as or different from each other.

8. The process for producing a syndiotactic α -olefin polymer according to claim 7, wherein in the general formula [1], R^5 and R^6 are aralkyl groups having 6 to 20 carbon atoms.

5

9. The process for producing a syndiotactic α -olefin polymer according to claim 1, wherein the at least one α -olefin having 3 to 10 carbon atoms is propylene.

10

10. A process for producing a syndiotactic α -olefin polymer according to claim 1, which comprises feeding ethylene and/or propylene to a polymerization reactor continuously or intermittently and the production process satisfies the relationship: $0.001 \leq P_E/P_O \leq 0.030$, provided that the molar amounts of ethylene and propylene are P_E and P_O , respectively.

15

11. The process for producing a syndiotactic α -olefin polymer according to claim 1, wherein the at least one α -olefin having 3 to 10 carbon atoms is 4-methyl-1-pentene.

20

12. The process for producing a syndiotactic α -olefin polymer according to any one of claims 1 to 6, wherein the syndiotactic α -olefin polymer comprises a structural unit X derived from at least one α -olefin selected from α -olefins

having 3 to 10 carbon atoms and a structural unit Y derived from ethylene, and satisfies all of the following requirements [1] to [4]:

[1] provided that the content of the structural unit X in the polymer is x (mol%) and the content of the structural unit Y in the polymer is y (mol%), $98.5 \leq x \leq 99.9$, $1.5 \geq y \geq 0.1$ and $x+y=100$;

[2] the racemic diad fraction ([r]) as measured by ^{13}C -NMR is $90\% \leq [r] < 100\%$;

[3] the intrinsic viscosity ($[\eta]$) as measured at 135°C in decalin is 0.70 dl/g or more; and

[4] the melting point (T_m) as determined by differential scanning calorimetry (DSC) is 145°C or higher.