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NEW ACTIVATOR SYSTEM FOR METALLOCENE COMPOUNDS

(57) Abstract

Supported olefin polymerization catalyst compositions prepared by contacting a support comprising a solid compound which is one of pure aluminum oxide, a mixed aluminum oxide, an aluminum halide, a magnesium halide, or a C1–C8 alkoxy magnesium halide, in any order with at least a) an organometallic compound of the general formula (1): RMX, wherein each R is the same or different and is a C1–C10alkyl group; M is a metal of Group 1, 2, 12 or 13 of the Periodic Table; each X is the same or different and one of a halogen atom, a hydrogen atom, a hydroxy radical or a C1–C8 hydrocarboxyloxy group; l is 1, 2 or 3; v is the oxidation number of the metal M, b) a metallocene of the general formula (2): (CpY)MOX,v,Zn,r wherein each CpY is one of a mono- or polysubstituted, fused or non-fused, homo- or heterocyclic cyclopentadienyl, indenyl, tetrahydroindenyl, fluorenyl, or octahydrofluorenyl ligand, which ligand is substituted at its cyclopentadienyl ring with at least one substituent Y which is one of a –OR, –SR, –NR2, – SiH or R')v=, or –PR'2 radical, each R' being one of a C1–C16 hydrocarboxy group, a tri-C1–C8 hydrocarboxyl silyl group or a tri-C1–C8 hydrocarboxyloxy silyl group; M' is a transition metal of Group 4 of the Periodic Table and bound to the ligand CpY at least in an 95 bonding mode, each X' is one of a hydrogen atom, a halogen atom, a C1–C8 hydrocarboxyl group, a C1–C8 hydrocarboxylheteroatom group or a tri-C1–C8 hydrocarboxylsilyl group or two X' form a ring with each other; Z is a bridge atom or group between two CpY ligands or one CpY ligand and the transition metal M'; m is 1 or 2; o is 0 or 1; and n is 4–m if Z is a bridge between two CpY ligands or n is a 4–m–o if Z is a bridge between one CpY ligand and the transition metal M'; and c) an aluminoxane of general formula (3).
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New activator system for metallocene compounds

The present invention relates to a process for the preparation of a supported olefin polymerization catalyst composition, comprising a support, a metallocene, and an aluminoxane. The invention also relates to a supported olefin polymerization catalyst composition which has been prepared according to said process and to the use of such a supported olefin polymerization catalyst composition for the polymerization of at least one olefin.

In many olefin polymerization processes using a single site catalyst, it is desirable to support the catalyst on a carrier or support. Usually such supported catalyst compositions include a metallocene and an aluminoxane supported on an inorganic oxide carrier such as silica and/or alumina.

For example, WO 96/00243 describes a method for producing a supported catalyst composition by mixing a bridged bis-indenyl metallocene and an aluminoxane in a solvent to form a solution, and then combining the solution and a porous support, whereby the total volume of the solution is less than that at which a slurry is formed. A typical support used was previously heated silica MS 948 (Grace) and a typical aluminoxane used was gel-free methyl aluminoxane (MAO), both of which were used in all of the examples.

According to S. Srinvasa Reddy, Polymer Bulletin, 36 (1996) 317-323, the ethylene polymerization activity of tetraisobutylaluminoxane cocatalyst was clearly lower than the activity of methylaluminoxane cocatalyst. This reflects the previous general opinion, that only methyl aluminoxane as a cocatalyst gave satisfactory ethylene polymerization catalyst activities.

The purpose of the present invention is to replace MAO as an olefin polymerization procatalyst. More specifically, the present invention aims at providing an olefin polymerization catalyst composition including a higher C2-C10 alkyl aluminoxane, which has commercially satisfactory activity when producing olefin homopolymers and copolymers. A further goal of the present invention is a supported olefin polymerization catalyst composition for use in gas phase, slurry phase or liquid/solution phase polymerizations.
The above mentioned purposes of the invention have now been realized by a novel process for the preparation of a supported olefin polymerization catalyst composition, comprising a support, a metallocene, and an aluminoxane. The claimed process is mainly characterized by contacting a support comprising a solid compound which is one of an aluminium oxide, a mixed aluminium oxide such as silica-alumina, an aluminium salt, a magnesium halide or a C₁-C₈ alkoxy magnesium halide, in any order with at least

a) an organometallic compound of the general formula (1):

\[ \text{R}_1\text{MX}_{\nu-1} \]  \hspace{1cm} (1)

wherein each R is the same or different and is a C₁-C₁₀ alkyl group; M is a metal of Group 1, 2, 12 or 13 of the Periodic Table (IUPAC 1990); each X is the same or different and one of a halogen atom, a hydrogen atom, a hydroxyl radical or a C₁-C₈ hydroxyalkoxy group; \( \nu \) is 1, 2 or 3; \( \nu \) is the oxidation number of the metal M,

b) a metallocene of the general formula (2):

\[ (\text{CpY})_m\text{M}'\text{X}'_n\text{Z}_0 \]  \hspace{1cm} (2)

wherein each CpY is the same or different and is one of a mono- or polysubstituted, fused or non-fused, homo- or heterocyclic cyclopentadienyl, indenyl, tetrahydroindenyl, fluorenyl, or octahydrofluorenyl ligand, the ligand being covalently substituted at its cyclopentadienyl ring with at least one substituent Y which is one of a -OR', -SR', -NR'R₂, -C(H or R')=, or -PR'R₂ radical, each R' being the same or different and being one of a C₁-C₁₆ hydrocarbyl group, a tri-C₁-C₈ hydrocarbyl silyl group or a tri-C₁-C₈ hydrocarbylsilyl group; M' is a transition metal of Group 4 of the Periodic Table and bound to the ligand CpY at least in an \( \eta_5 \) bonding mode; each \( \text{X}' \) is the same or different and is one of a hydrogen atom, a halogen atom, a C₁-C₈ hydrocarbyl group, a C₁-C₈ hydrocarbylheteroatom group or a tri-C₁-C₈ hydrocarbylsilyl group or two \( \text{X}' \) form a ring with each other; \( \text{Z} \) is a bridge atom or group between two CpY ligands or one CpY ligand and the transition metal M'; m is 1 or 2; o is 0 or 1; and n is 4-m if there is no bridge Z or Z is a bridge between two CpY ligands or n is 4-m-0 if Z is a bridge between one CpY ligand and the transition metal M', and

c) an aluminoxane of the following general formulas (3):
wherein each $R''$ and each $R'''$ is the same or different and is a C$_2$-C$_{10}$ alkyl group; and $p$ is an integer between 1 and 40, and recovering said supported olefin polymerization catalyst composition.

By mono- or polysubstituted is meant that, in addition to said substituent $Y$, there may optionally be other substituents at the rings at said ligands Cp$Y$.

By fused or non-fused is meant that any ring at said ligands may be fused or non-fused, i.e. have at least two atoms in common, with at least one further ring.

By homo- and heterocyclic is meant that any ring of said ligands may have only carbon ring atoms (homo- or isocyclic) or may have other ring atoms than carbon (heterocyclic).

It has thus been realized that a C$_2$-C$_{10}$ alkyl aluminoxane (i.e. a non-methyl aluminoxane) can successfully be used as the cocatalyst, if a support comprising an aluminium pure oxide, mixed oxide or salt, or a magnesium halide, is first treated with a metal alkyl compound and then activated with a metallocene having a -OR', -SR', -NR'$_2$, -C(H or R')=, or -PR'$_2$ substituent at the cyclopentadienyl ring.

According to non-limiting model, said electron pair of double bond substituents at the cyclopentadienyl ring delocalize it's negative charge and help to ionise the metallocene, whereby the transition metal M becomes more cationic (electron density deficient). By combining this with special methyl alkyl treatment of acidic surfaces (like alumina, aluminium phosphate, silica-alumina, etc...) the cationisation can be enhanced. This improves the catalytic interaction between the metallocene
and the aluminoxane and enables the use of higher aluminoxanes like those of the above formula (3).

Generally, said support can be contacted with compounds a), b) and c) in any order.

Thus, the support can e.g. be impregnated with a solution of the three compounds a), b) and c), first with compound a) and then with a solution containing compound b) and compound c), or preferably, contacting said support at first with a) said organometallic compound of the general formula (1), then with

b) said metalloocene of the general formula (2), and after that with

c) said aluminoxane of the general formulas (3).

According to one embodiment of the invention, the contacting of the support with compounds a), b) and c) takes place by contacting the support with one or several solutions of the compounds. The support can, for example, be contacted with a solution of said organometallic compound (1) and thereafter with a solution containing said metalloocene (2) and said aluminoxane (3). In a preferable embodiment of the invention, the contacting takes place by

a) contacting said support with a solution of said organometallic compound (1), and removing the supernatant from the contacting product,

b) contacting the product of step a) with a solution of said metalloocene (2), and removing the supernatant from the contacting product, and

c) contacting the product of step b) with a solution of said aluminoxane (3), and removing the supernatant from the contacting product.

When contacting said support with compounds a), b) and c) in liquid form such as the form of a solution, a slurry or a non-slurry contacting product can be formed. However, it is preferable to impregnate the support with a liquid, the volume of which is less than at which a slurry is formed. This means that the volume of said liquid is less than or approximately equal to the volume of the support pores.

The support used in the process of the present invention is a support comprising a solid compound which is one of a pure aluminiumoxide, a mixed aluminiumoxide, an aluminium salt, a magnesium halide or a C1-C8 alkoxy magnesiumhalide. A typical aluminium salt is aluminium phosphate AlPO4. According to preliminary experiments pure silica did not give high activity olefin polymerization catalysts when combined with a C2-C10 alkyl aluminoxane according to formula (3) and a
metalocene according to formula (2). In the claimed process, however, the support comprising, i.e. consisting of, containing, or having carried thereupon said solid compound, gives high activity with compounds (2) and (3). It is believed (non-limiting) that the supports listed above are more acidic than silica and, thanks to their nature as Lewis-acids, contribute to the activation of said metalloccenes and said higher aluminoxanes. The material carrying said compound can be any inert particulate material, including silica. The most preferable support comprises a porous aluminium oxide, most preferably alumina, which has been heated to a temperature between 100-1000 °C. The aluminium oxide, preferably the calcined alumina, is preferentially in the form of, or deposited on, particles having a diameter of between 10-500 μm, most preferably between 20 and 200 μm. The specific surface area of the aluminium oxide or calcined alumina is according to one embodiment of the invention between 50 and 600 m²/g, preferably between 100 and 500 m²/g. The average pore volume is usually between 0.5 and 5.0 ml/g, preferably between 1.0 and 2.5 ml/g. The average pore diameter is for example 100-500 Å, preferably approximately 200 Å.

According to the process of the present invention, the support is contacted with a) an organometallic compound of the general formula (1):

\[
R_1MX_{v-1}
\]  

(1)

wherein each R is the same or different and is a C₁-C₁₀ alkyl group; M is a metal of Group 1, 2, 12 or 13 of the Periodic Table; each X is the same or different and one of a halogen, a hydrogen atom, a hydroxyl radical or a C₁-C₈ hydrocarbyloxy group; l is 1, 2 or 3; and v is the oxidation number of the metal M.

According to a non-limiting theoretical model, the organometallic compound alkylates said solid compound of the support, which in turn alkylates and activates the metal of the metalocene. This is then reflected in the successful use of otherwise poorly active higher aluminoxanes.

The C₁-C₁₀ alkyl group R of formula (1) is preferably a C₁-C₆ alkyl group and most preferably a C₁-C₄ alkyl group. When defining M by means of the Groups and Periods of the Periodic Table, the new numbering system is used (IUPAC 1990). Preferred metals M are those of Periods 1-4 of the Periodic Table.
If occurring, X of formula (1) is a halogen atom, a hydrogen atom, a hydroxyl radical or a hydrocarbylloxoy group. According to one preferable embodiment of the invention, said support is contacted with

a) said organometallic compound of the general formula (1), which is one of a C₁-C₁₀ alkyl lithium, a C₁-C₁₀ dialkyl magnesium, or a C₁-C₁₀ trialkyl aluminium, and most preferably is a C₁-C₆ trialkyl aluminium such as trimethyl aluminium (TMA). When contacting said support with said organometallic compound, it is preferable if the organometallic compound of the formula (1) is immersed or dissolved in a hydrocarbon medium, most preferably a C₄-C₁₀ hydrocarbon medium. The weight ratio between the added organometallic compound, calculated as trimethyl aluminium, and the support depends on the surface area, pore volume and diameter, surface hydroxyl number and type. According to one embodiment it is between 0.1 and 10, more preferably between 0.2 and 2 and most preferably between 0.3 and 1.5. After the contacting step the remaining unreacted organometallic compound is preferably removed together with the possible hydrocarbon medium, followed by optional washing steps.

According to the process of the present invention said support is contacted with

b) a metallocene of the general formula (2). It is preferred that the metallocene of the general formula (2) as group R' of said substituent Y has a tri-C₁-C₈ hydrocarbyl silyl or tri-C₁-C₈ hydrocarbyloxy silyl group. Especially suitable tri-C₁-C₈ hydrocarbylsilyl groups are those capable of π interaction with said O, S, N, or P atoms of Y. Most preferred are tri-C₁-C₈ alkyl silyl groups, wherein at least one of the C₁-C₈ alkyls is a branched C₃-C₈ alkyl group such as isopropyl, isobutyl, sec-butyl, tert-butyl, isoamyl, sec-amyl, tert-amyl, isohexyl, sec-hexyl, or tert-hexyl. Cyclic alkyls and aryls are also preferred groups of the silicone atom.

According to one embodiment of the invention there is only one ligand CpY in the metallocene of formula (2), which preferably is bound to the transition metal M' by both said η₅ bond and by a bridge Z preferably containing a heteroatom.

However, said metallocene of the general formula (2) has most preferably two ligands CpY, i.e. m is 2. According to a still more preferred embodiment, the two CpY ligands are bridged with each other by a bivalent atom or group Z having at least one chain atom which is one of a carbon, silicon, oxygen, sulphur, nitrogen, or phosphorous atom. Most preferably, the metallocene of the general formula (2) has m=2, whereby Z is an ethylene or a silylene bridge.
The transition metal M' of group 4 of the Periodic Table in the general formula (2) is Ti, Zr or Hf, more preferably Zr or Hf, and most preferably Zr. The valency or oxidation number of M' is 4.

In the definition of X' above, a heteroatom means -O-, -S-, -\(\frac{1}{2}\)-, or -\(\frac{1}{3}\)-.

The preferable atom or group X' of said metalloocene of formula (2) is a halogen atom and/or a C\(_1\)-C\(_8\) hydrocarbyl group. Most preferably, X' is chlorine and/or methyl. The number of X' atoms or groups, i.e. "n", is preferably 1-3, most preferably 2, considering the limitation given above for the case when Z is a bridge between CpY and M'.

Particularly preferred metalloocenes of the general formula (2) are compounds of the following structural formula (4).

![Structural formula (4)](image)

wherein Y\(_1\) and Y\(_2\) are the same or different and are one of a hydrogen atom, a halogen atom, an acyl group, an acyloxy group, a C\(_1\)-C\(_{10}\) hydrocarbyl group, a -OR', -SR', -NR', -C(H or R')=, or -PR'\(_2\) radical, R' being one of a C\(_1\)-C\(_{16}\) hydrocarbyl group or a tri-C\(_1\)-C\(_8\)-hydrocarbylsilyl group, provided that at least one of Y\(_1\) and Y\(_2\) is one of said -OR', -SR', -NR', -C(H or R')=, or -PR'\(_2\) radicals; Z is a bivalent atom or group having at least one chain atom which is one of a carbon, silicon, oxygen, sulphur, nitrogen or phosphorus atom, preferably 1-4 carbon and/or silicon chain atoms; each R\(_V\) is the same or different and is one of a hydrogen atom, a halogen atom, a C\(_1\)-C\(_{10}\) hydrocarbyl group or ring constituent, or a C\(_1\)-C\(_{10}\)
hydrocarbyloxy group, M' is one of Ti, Zr or Hf; and X', and X" are the same or
different and are one of a halogen atom and a C₁-C₈ hydrocarbyl group. The
analogous 4,5,6,7-tetrahydroindeny1 derivatives are also useful in the invention.

A representative metalloocene of the formula (2) is ethylene-bis(2-tert-butyldimethyl-
siloxyindeny1) zirconium dichloride.

When using chiral metalloeces, they can be used as a racemate for the preparation
of highly isotactic α-olefin polymers. The pure R or S form of said metalloocene can
also be used, e.g. for the production of optically active polymer.

The metalloocene of the general formula (2) is usually prepared by a process
involving repeated deprotonations/metalizations of the aromatic ligands and
introduction of the bridge Z atom or atoms as well as the central atom by their
halogen derivatives. The preparation of the said metalloocene of the general formula
(2) can e.g. be carried out according to a J. Organometallic Chem. 288 (1958) 63-67

The most preferred metalloeces of the general formula (2), wherein Y is a tri-C₁-
C₈ hydrocarbylsiloxy group, is preferably prepared as follows:

The catalyst compounds according to the invention can be prepared from 2-
indanone. This compound can be reacted in a suitable solvent with a base and a
chlorosilane to form 2-siloxycyclohexene with a yield of over 80%. Suitable solvents are
for example dimethylformamide (DMF) and tetrahydrofurane (THF). Suitable bases
are for example imidazole and triethylamine (TEA). Suitable chlorosilanes are for
example tert-butyldimethylchlorosilane, t-hexyldimethylchlorosilane and cyclo-
hexyldimethylchlorosilane. The reaction takes place according to the following
reaction scheme (II):

\[
\begin{array}{c}
\text{O} \quad \text{M} \quad \text{Me} \\
\text{Me} \\
\end{array}
\]
According to one embodiment of the invention 2-tert-butylidimethylsiloxyindene is reacted first with butyllithium and then with dimethyl dichlorosilane (Me₂SiCl₂) to form dimethylsilylbis(2-tert-butylidimethylsiloxyindene). Butyllithium can be replaced with methylolithium, sodium hydride or potassium hydride. Likewise dimethyl dichlorosilane can be replaced with any dialkyl or diarylsilane. Silicon can be replaced with germanium.

Dimethylsilylbis(2-tert-butylidimethylsiloxyindene) can be reacted with butyllithium, which gives the corresponding bislithium salt. This product can be reacted with zirconium tetrachloride to yield dimethylsilyl[(2-tert-butylidimethylsiloxyindenyl)]zirconium dichloride as a mixture of the racemic and meso diastereomers. Butyllithium may be replaced as described earlier. Zirconium tetrachloride can be replaced with titanium tetrachloride or hafnium tetrachloride to give the corresponding titanium and hafnium complexes. The reactions take place according to the following reaction schemes (III-IV):
According to another embodiment of the invention 2-tert-butyldimethylsiloxindene is reacted first with butyllithium and then with dibromoethane to form bis(2-tert-butylidimethylsiloxindenyldenyl)ethane. This compound can be reacted with two equivalents of butyllithium, which gives the corresponding bislithium salt. This can then be reacted with zirconium tetrachloride to yield ethylenebis(2-tert-butyldimethylsiloxindenyldenyl)zirconium dichloride. The racemic diastereomer of the latter is formed in great excess and is easily separated from the meso isomer by fractional crystallization. Catalytic hydrogenation of racemic ethylenebis(2-tert-butyldimethylsiloxindenyldenyl)zirconium dichloride yields the corresponding tetrahydroindenyldenyl complex. The reaction takes place according to the following reaction scheme (V):

\[
\begin{align*}
\text{Me} & \quad \text{Me} & \quad \text{1) BuLi} & \quad 2) 0.5 \text{Br}_{2} \text{C}_{2} \text{CH}_{2} \text{Br} \\
\text{Me} & \quad \text{t-Bu} & \quad \text{Si} & \quad \text{O} & \quad \text{Si} & \quad \text{t-Bu} \\
\text{Me} & \quad \text{t-Bu} & \quad \text{Si} & \quad \text{O} & \quad \text{Si} & \quad \text{t-Bu} \\
\text{Me} & \quad \text{t-Bu} & \quad \text{Si} & \quad \text{O} & \quad \text{Si} & \quad \text{t-Bu} \\
\text{1) 2 BuLi} & \quad \text{2) ZrCl}_{4} & \quad \text{THF} & \quad \text{ZrCl}_{4} & \quad \text{Cl} & \quad \text{Cl} \\
\text{PtO}_{2}/\text{H}_{2}/80 \text{bar} & \quad \text{CH}_{2} \text{Cl}_{2} & \quad \text{Cl} & \quad \text{ZrCl}_{4} & \quad \text{Cl} & \quad \text{Cl} 
\end{align*}
\]
In the reactions above butyllithium may be replaced as described earlier. Zirconium tetrachloride can be replaced with titanium tetrachloride or hafnium tetrachloride to give the corresponding titanium and hafnium complexes.

According to still another embodiment of the invention 2-t-hexyldimethylsiloxylindene is reacted first with butyllithium and then with dibromoethane to form bis(2-t-hexyldimethylsiloxylindeny1)ethane. This compound can be reacted with two equivalents of butyllithium which gives the corresponding bislithium salt. This can then be reacted with zirconium tetrachloride to yield ethylenebis(2-t-hexyldimethylsiloxylindeny1)zirconium dichloride. The racemic diastereomer of the latter is formed in great excess and is easily separated from the meso isomer by fractional crystallization. The reaction takes place according to the following reaction scheme (VI):

In the reactions above butyllithium may be replaced as described earlier. Zirconium tetrachloride can be replaced with titanium tetrachloride or hafnium tetrachloride to give the corresponding titanium and hafnium complexes. Hydrogenation of ethyl-
enebisl(2-t-hexyldimethylsiloxyindenyl)zirconium dichloride yields the corresponding tetrahydroindenyl complex.

Illustrative but non-limiting examples of the preferable compounds used according to the invention are, among others, racemic and meso dimethylsilylbis(2-tert-butylldimethylsiloxyindenyl)zirconium dichloride, racemic and meso diphenylsilylbis(2-tert-butylldimethylsiloxyindenyl)zirconium dichloride, racemic and meso dimethylsilylbis(2-t-hexyldimethylsiloxyindenyl)zirconium dichloride, racemic and meso diphenylsilylbis(2-t-hexyldimethylsiloxyindenyl)zirconium dichloride, racemic and meso dimethylsilylbis(2-cyclohexyldimethylsiloxyindenyl)zirconium dichloride, racemic and meso dimethylsilylbis(2-tert-butylldiphenylsiloxyindenyl)zirconium dichloride, racemic and meso dimethylsilylbis(2-tert-butylldimethylsiloxy-4,5,6,7-tetrahydroindenyl)zirconium dichloride, racemic and meso dimethylsilylbis(2-t-hexyldimethylsiloxy-4,5,6,7-tetrahydroindenyl)zirconium dichloride, racemic and meso diphenylsilylbis(2-tert-butylldimethylsiloxy-4,5,6,7-tetrahydroindenyl)zirconium dichloride, racemic and meso dimethylsilylbis(2-tert-butylldiphenylsiloxy-4,5,6,7-tetrahydroindenyl)zirconium dichloride, racemic and meso diphenylsilylbis(2-t-hexyldimethylsiloxy-4,5,6,7-tetrahydroindenyl)zirconium dichloride, racemic and meso dimethylsilylbis(2-cyclohexyldimethylsiloxy-4,5,6,7-tetrahydroindenyl)zirconium dichloride, racemic and meso diphenylsilylbis(2-cyclohexyldimethylsiloxy-4,5,6,7-tetrahydroindenyl)zirconium dichloride, racemic and meso ethylenebis(2-t-hexyldimethylsiloxyindenyl)zirconium dichloride, racemic and meso ethylenebis(2-cyclohexyldimethylsiloxyindenyl)zirconium dichloride, racemic and meso ethylenebis(2-tert-butylldiphenylsiloxyindenyl)zirconium dichloride, racemic and meso ethylenebis(2-tert-butylldimethylsiloxy-4,5,6,7-tetrahydroindenyl)zirconium dichloride, racemic and meso ethylenebis(2-tert-butylldiphenylsiloxy-4,5,6,7-tetrahydroindenyl)zirconium dichloride and rac-ethylenebis(2-t-hexyldimethylsiloxyindenyl)zirconium dichloride. Titanium or hafnium can be used instead of zirconium in corresponding complexes.
When contacting said support, comprising a solid compound which is one of a pure aluminium oxide, a mixed aluminium oxide, an aluminium salt, a magnesium halide or a C₁-C₈ alkoxy magnesium halide, with
b) said metallocene of the general formula (2), the metallocene is preferably dissolved in a C₄-C₁₀ hydrocarbon solvent and most preferably in an aromatic hydrocarbon solvent such as toluene. As was said before, the metallocene hydrocarbons solution may also contain an alumoxane. The solution is then contacted with the support, which generally is porous.

It is also advantageous, if the total volume of the solution added to the support is less than the volume required to form a support slurry and, according to one embodiment, equal to or less than the pore volume of the support.

Although the amount of metallocene may very much e.g. due to the structure of the support, according to one embodiment of the present invention, the support is contacted with
b) said metallocene of the formula (2) at a molar to weight ratio between the metallocene and the support of between 0.001 to 0.50 mmol/g, more preferably 0.010 to 0.10 mmol/g, most preferably 0.02 to 0.08 mmol/g.

In the present process for the preparation of a supported olefin polymerization catalyst composition, the support is contacted with
c) an aluminoxane of the general formulas (3). Formulas (3) are general formulas including not only linear and cyclic compounds, but also aluminoxane compounds of cage and net structures. See e.g. Harlan, et.al., J. Am Chem. Soc., 117, (1995) p. 6466, the aluminoxane structures of which are enclosed by reference to disclose one embodiment of the invention.

The aluminoxane used in the process of the present invention is preferably an aluminoxane (3), wherein said R", and optionally said R"" is a C₃-C₁₀ alkyl group, more preferably an isopropyl, isobutyl, sec-butyl, tert-butyl, isoamyl, sec-amyl, tert-amyl, isoheptyl, sec-heptyl or tert-heptyl group. The most preferred aluminoxane of the formula (3) is preferably an aluminoxane in which 2 ≤ n ≤ 12, most preferably 4 ≤ n ≤ 8. A suitable aluminoxane of the formula (3) is hexa(isobutylaluminoxane). The aluminoxane according to the present invention can be prepared analogously to or by modifying a variety of methods for preparing aluminoxane, non-limiting examples of which are described in US 4,665,208, 4,952,540, 5,091,352, 5,206,199, 5,204,419, 4,874,734, 4,924,018, 4,908,463, 4,968,827;

It is preferable to contact said support previous to, immediately before, or at the beginning of the olefin polymerization, with

c) an aluminoxide of formula (3) dissolved or immersed in a hydrocarbon solvent, most preferably a C<sub>4</sub>-C<sub>12</sub> aliphatic hydrocarbon solvent such as hexane.

When contacting said support with said organometallic compound of the formula (1), said metallocene of the formula (2), and said aluminoxide of the formula (3), the molar ratio between the aluminoxide aluminium metal and the metallocene transition metal M' in the catalyst composition is preferably between 20 and 500, more preferably 30 and 300 and most preferably between 40 and 200. Even more preferably, said ratio is between 80 and 200.

When preparing a supported olefin polymerization catalyst composition according to the present invention, the contacting product between the support, the organometallic compound of the general formula (1), the metallocene of the general formula (2) and the aluminoxide of the general formula (3) can be subjected to a pre polymerization with at least one olefin such as propylene and/or ethylene. The pre polymerizate is then recovered as said supported olefin polymerization catalyst composition.

In addition to the above described process for the preparation of a supported olefin polymerization catalyst composition, the present invention also relates to a supported olefin polymerization catalyst composition which has been prepared according to said described process. The invention also relates to a process for polymerizing at least one olefin by polymerizing in the presence of a supported olefin polymerization catalyst prepared according to the above described process. In the polymerization (homopolymerization and copolymerization) olefin monomers, such as ethylene, propylene, 1-butylene, isobutylene, 4-methyl-1-pentene, 3-methyl-1-butene, 4,4-dimethyl-1-pentene, vinyl cyclohexene and their comonomers, can be used. Dienes and cyclic olefins can also be homo- or copolymerized. These α-olefins and other monomers can be used both in the polymerization and prepolymerization of the claimed supported olefin polymerization catalyst composition.

The polymerization can be a homopolymerization or a copolymerization and it can take place in the gas, slurry or a solution phase. The claimed catalyst composition can also be used in high pressure processes. Said α-olefins can be polymerized
together with higher α-olefins in order to modify the properties of the final product. Such higher olefins are 1-hexene, 1-octene, 1-decene, etc.

In the following, the present invention is illustrated by non-limited examples.

EXAMPLES

Example 1
Catalyst preparation

Alumina calcination
In the most of the catalysts, the carrier used was Alumina B. Catalyst (by Akzo, calcined 4 hours at 600 °C).

Trimethylaluminium treatment of alumina
In these catalysts, alumina was treated with TMA (trimethylaluminium, 20% in pentane): 3 ml of the TMA solution was added to 1 g of alumina, allowed to react for 2 hours, then 10 ml pentane was added and the compounds were allowed to react further for 30 minutes. Then the excess of pentane was decanted away and this "washing" was repeated 3 times under nitrogen without stirring.

Impregnation of metallocene compound
After the TMA treatment, said alumina was treated with the 20 mg of rac-ethylene-bis(2-tert-butylmethylsiloxyindenyl)zirconium dichloride diluted in toluene, allowed to react and dried.

Test polymerization
Polymerization was carried out in a 2-liter Büchi autoclave in i-butane. The ethylene partial pressure was 5 bar, the temperature was 80 °C and the reaction time was 1 hour. 201 mg of catalyst was fed into the autoclave together with 0.6 ml of 20 w-% HIBAO (= hexaisobutylaluminoxane) giving an Al/Zr- ratio of 60. After 1 h of polymerization the yield of HDPE was 140 g giving an activity of the catalyst of 0.7 kgHDPE/ g cat h (= 259 kgPE/ g Zr h).
Example 2
Catalyst preparation

Alumina calcination and trimethylaluminium treatment of alumina

See example 1

Impregnation of metallocene compound
After TMA treatment, said TMA-treated alumina was further treated with 40 mg of rac-ethylenebis(2-tert-butyldimethylsiloxyindenyl)zirconium dichloride diluted in 1.5 ml toluene, allowed to react for 2 h and dried under N₂ blow for 2 h 30 min.

Test polymerization
Polymerization was carried out in a 2-liter Büchi autoclave in a i-butane. The ethylene partial pressure was 5 bar, the temperature was 80 °C and the reaction time was 1 hour. 98 mg of catalyst was fed into the autoclave together with 0.3 ml of 20 w-% HIBAO (= hexaisobutylaluminoxane) giving an Al/Zr-ratio of 60. After 1 h of polymerization the yield of HDPE was 219 g giving a catalyst activity of 2.0 kgHDPE/ g cat h (= 416 kgPE/ g Zr h).

Example 3
Catalyst preparation

Alumina calcination
In the most of the catalysts, the carrier used was alumina B. Catalyst (by Akzo, calcinated 4 hours at 600 °C).

Trimethylaluminium treatment of alumina
In these catalysts, alumina was treated with TMA (trimethylaluminium, 20% in pentane): 50 ml TMA solution was added to 10.14 g of alumina, allowed to react for 2 hours, then 100 ml pentane was added and allowed to react further for 1 h 30 minutes. Then the excess pentane was decanted and this "washing" was repeated 3 times with 100 ml of pentane to remove the unreacted TMA.

Impregnation of metallocene compound
After the TMA treatment, the alumina was treated with 401 mg of rac-ethylenebis-(2-tert-butyldimethylsiloxyindenyl)zirconium dichloride diluted in 10 ml toluene, allowed to react 30 minutes and dried. After drying the catalyst was washed 6 times with 100 ml of pentane to remove unreacted metallocene.
Test polymerization
Polymerization was carried out in a 2-liter Büchi autoclave in i-butane. The ethylene partial pressure was 5 bar, the temperature was 80 °C and the reaction time was 1 hour. 104 mg of catalyst was fed to the autoclave together with 0.15 ml of 20 w-% HIBAO (= hexaisobutylaluminoxane) giving an Al/Zr-ratio of 30. After 1 h of polymerization the yield of HDPE was 128 g giving a catalyst activity of 1.2 kgHDPE/ g cat h ( = 240 kgPE/ g Zr h).

Example 4
Catalyst preparation

Catalyst preparation according to Example 3

Test polymerization
Polymerization was carried out in a 2-liter Büchi autoclave in i-butane. The ethylene partial pressure was 5 bar, the temperature was 80 °C and the reaction time was 1 hour. 100 mg of catalyst was fed into the autoclave together with 0.3 ml of 20 w-% HIBAO (= hexaisobutylaluminoxane) giving an Al/Zr-ratio of 60. After 1 h of polymerization the yield of HDPE was 170 g giving a catalyst activity of 1.6 kgHDPE/ g cat h ( = 320 kgPE/ g Zr h).

Example 5
Catalyst preparation

Catalyst preparation according to Example 3

Test polymerization
Polymerization was carried out in a 2-liter Büchi autoclave in i-butane. The ethylene partial pressure was 5 bar, the temperature was 80 °C and the reaction time was 1 hour. 99 mg of catalyst was fed into the autoclave together with 0.6 ml of 20 w-% HIBAO (= hexaisobutylaluminoxane) giving an Al/Zr-ratio of 120. After 1 h polymerization the yield of HDPE was 231 g giving a catalyst activity of 2.7 kgHDPE/ g cat h ( = 540 kgPE/ g Zr h).
Example 6
Catalyst preparation

Catalyst preparation according to Example 3

Test polymerization
Polymerization was carried out in a 2-liter Büchi autoclave in i-butane. The ethylene partial pressure was 5 bar, the temperature was 80 °C and the reaction time was 1 hour. 104 mg of catalyst was fed into the autoclave together with 2.6 ml of 20 w-% HIBAO (= hexaisobutylaluminoxane) giving an Al/Zr-ratio of 520. After 1 h polymerization the yield of HDPE was 238 g giving a catalyst activity of 2.3 kgHDPE/ g cat h (= 460 kgPE/ g Zr h).

Example 7
Catalyst preparation

Catalyst preparation according to Example 3

Test polymerization
Polymerization was carried out in a 2-liter Büchi autoclave in i-butane. The ethylene partial pressure was 5 bar, 20 ml of 1-butene was added after 15 min of homopolymerization as a comonomer, the temperature was 80 °C and the reaction time was 1 hour. 109 mg of catalyst was fed into the autoclave together with 0.6 ml of 20 w-% HIBAO (= hexaisobutylaluminoxane) giving an Al/Zr-ratio of 120. After 1 h of polymerization the yield of HDPE was 124 g giving a catalyst activity of 1.14 kgHDPE/ g cat h (= 230 kgPE/ g Zr h).

Polymer properties:
Comonomer content was measured by FT-IR. The polymer was containing 1.5 w-% butene as a comonomer indicating good comonomer response.
Example 8
Catalyst preparation

Catalyst preparation according to Example 3

Test polymerization
Polymerization was carried out in a 2-liter Büchi autoclave in i-butane. The ethylene partial pressure was 5 bar, 40 ml of 1-butene was added after 15 min of polymerization as a comonomer, the temperature was 80 °C and the reaction time was 1 hour. 110 mg of catalyst was fed into the autoclave together with 0.6 ml of 20 w-% HIBAO (= hexaisobutylaluminoxane) giving an Al/Zr-ratio of 120. After 1 h of polymerization the yield of HDPE was 124 g giving a catalyst activity of 1.75 kgHDPE/ g cat h (= 350 kgPE/ g Zr h).

Polymer properties:
Comonomer content was measured by FT-IR. The polymer was containing 2.9 w-% butene as a comonomer indicating good comonomer response.

Example 9
Catalyst preparation

Catalyst preparation according to Example 3

Test polymerization
Polymerization was carried out in a 2-liter Büchi autoclave in i-butane. The ethylene partial pressure was 5 bar, 60 ml of 1-butene was added after 15 min of polymerization as a comonomer, the temperature was 80 °C and the reaction time was 1 hour. 100 mg of catalyst was fed into the autoclave together with 0.6 ml of 20 w-% HIBAO (= hexaisobutylaluminoxane) giving an Al/Zr-ratio of 120. After 1 h of polymerization the yield of HDPE was 124 g giving a catalyst activity of 1.8 kgHDPE/ g cat h (= 360 kgPE/ g Zr h).

Polymer properties:
Comonomer content was measured by FT-IR. The polymer was containing 4.2 w-% butene as a comonomer indicating good comonomer response.
Example 10
Catalyst preparation

Catalyst preparation according to Example 3

Test polymerization
Polymerization was carried out in a 2-liter Büchi autoclave in i-butane. The ethylene partial pressure was 5 bar, 80 ml of i-butene was added after 15 min of polymerization as a comonomer, the temperature was 80 °C and the reaction time was 1 hour. 92 mg of catalyst was fed into the autoclave together with 0.6 ml of 20 w-% HIBAO (= hexaisobutylaluminoxane) giving an Al/Zr-ratio of 120. After 1 h of polymerization the yield of HDPE was 124 g giving a catalyst activity of 2.2 kgHDPE/ g cat h (= 440 kgPE/ g Zr h).

Polymer properties:
Comonomer content was measured by FT-IR. The polymer was containing 4.6 w-% butene as a comonomer indicating good comonomer response.

Example 11 (comparative; using silica)
Catalyst preparation

Silica gel calcination
The silica used was Sylopol 55 SJ, calcinated for 4 hours at 600 °C.

Methylation of Silica Sylopol 55 SJ
Silica was TMA treated identically to alumina. In these catalysts, silica was first treated with TMA (trimethylaluminium, 20% in pentane): 4.5 ml of the TMA solution was added to 1 g of silica, allowed to react for 2 hours, then 10 ml pentane was added and the compounds were allowed to react further for 30 minutes. Then the excess of pentane was decanted away and this "washing" was repeated twice. The mixture was dried under nitrogen for one hour. During this drying process, magnetic stirring was used.

Impregnation of metallocene compound
After the TMA treatment, the silica was treated with 20 mg of rac-ethylenebis(2-tert-butyl(dimethylsiloxy)indenyl)zirconium dichloride diluted in 1.5 ml of toluene, allowed to react and dried.
Test polymerization
Polymerization was carried out in a 2-liter Büchi autoclave in i-butane. The ethylene partial pressure was 5 bar, the temperature was 80 °C and the reaction time was 1 hour. 195 mg of catalyst was fed into the autoclave together with 0.6 ml of 20 w-% HIBAO (= hexaisobutylaluminoxane) giving an Al/Zr-ratio of 120. After 1 h of polymerization the yield of HDPE was 22 g giving a catalyst activity of only 0.1 kgHDPE/ g cat h (= 40 kgPE/ g Zr h).

Example 12 (comparative; no HIBAO)

Catalyst preparation

Catalyst preparation as in Example 1

Test polymerization
Polymerization was carried out in a 2-liter Büchi autoclave in i-butane. The ethylene partial pressure was 5 bar, the temperature was 80 °C and the reaction time was 1 hour. 210 mg of catalyst was fed into the autoclave without any cocatalyst. After 1 h of polymerization the yield of HDPE was 9 g giving a catalyst activity of only 0.04 kgHDPE/ g cat h (= 16 kgPE/ g Zr h).

Example 13 (comparative; TMA instead of HIBAO)

Catalyst preparation

Catalyst preparation like Example 1

Test polymerization
Polymerization was carried out in a 2-liter Büchi autoclave in i-butane. The ethylene partial pressure was 5 bar, the temperature was 80 °C and the reaction time was 1 hour. 202 mg of catalyst was fed into the autoclave with 0.3 ml of TMA (= trimethylaluminium 20 w-% in pentane). After 1 h of polymerization the yield of HDPE was 1 g giving a catalyst activity of only 0.01 kgHDPE/ g cat h (= 2 kgPE/ g Zr h).
Example 14 (comparative; no TMA treatment)
Catalyst preparation

Alumina calcination

In the most of the catalysts, the carrier used was Alumina B. Catalyst (by Akzo, calcinated 4 hours in 600 °C).

Trimethylaluminium treatment of alumina
No TMA treatment

Impregnation of metallocene compound
1 g alumina was treated with 20 mg of rac-ethylenebis(2-tert-butyldimethylsiloxyindenyl)zirconium dichloride diluted in 1,5 ml toluene, allowed to react for 1 h and dried under N₂ for 1 h.

Test polymerization
Polymerization was carried out in a 2-liter Büchi autoclave in i-butane. The ethylene partial pressure was 5 bar, the temperature was 80 °C and the reaction time was 1 hour. 130 mg of catalyst was fed into the autoclave together with 0.8 ml of 20 w-% HIBAO (= hexaisobutylaluminoxane) giving an Al/Zr-ratio of 240. After 1 h of polymerization the yield of HDPE was 3 g giving a catalyst activity of 0.02 kgHDPE/ g cat h (= 9 kgPE/ g Zr h).

Example 15
Catalyst preparation

Silica-Alumina calcination
In the most of the catalysts, the carrier used was Silica-Alumina where alumina is enriched onto silica surface (by GRACE, calcinated 4 hours in 600 °C).

Trimethylaluminium treatment of Silica-Alumina
In these catalysts, silica-supported alumina was treated with TMA (trimethylaluminium, 20% in pentane): 50 ml of the TMA solution was added to 10 g of silica-alumina, allowed to react for 2 hours, then 100 ml pentane was added and the compounds were allowed to react further for 1 h 30 minutes. Then the excess of pentane was decanted off and this "washing" was repeated 3 times with 100 ml of pentane to remove unreacted TMA.
Impregnation of metallocene compound
After the TMA treatment, the alumina was treated with the 400 mg of rac-
ethylenebis(2-tert-butylidimethylsiloxyindenyl)zirconium dichloride diluted in 10 ml
of toluene, allowed to react 30 minutes and dried. After drying catalyst was washed
6 times with 100 ml of pentane for washing unreacted metallocene compound away.

Test polymerization
Polymerization was carried out in a 2-liter Büchi autoclave in i-butane. The
ethylene partial pressure was 5 bar, the temperature was 80 °C and the reaction time
was 1 hour. 120 mg of catalyst was fed into the reactor together with 96 ml of
20 w-% HIBAO (= hexaisobutylaluminoxane) giving an Al/Zr-ratio of 120. After
1 h of polymerization the yield of HDPE was 322 g giving a catalyst activity of
2,7 kgHDPE/ g cat h (= 540 kgPE/ g Zr h).

Example 16
Catalyst preparation
Catalyst preparation according to example 3.

Test polymerisation
Polymerization was carried out in a 3-liter Büchi autoclave in a liquid propylene.
Propylene pressure was 31 bars, and temperature 70 °C and reaction time was
1 hour. Into reactor 120 mg of catalyst was fed together with 0,6 ml of 20 w-%
HIBAO (= hexaisobutylaluminoxane) giving Al/Zr-ratio 120. After 1 h
polymerization the yield of PP was 23,2 g giving activity of catalyst 0,2 kgPP/g cat h
(= 49 kgPE/g Zr h).

Polymer properties:
Xylene soluble fraction was 3 w-% indicating isotacticity index > 97%. The
molecular weight of polypropylene was Mw = 36 000, Mn = 17 000 and poly-
dispersity 2.1 indicating single site catalyst behaviour.

In the following table, the parameters and results of the examples are disclosed.
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<tr>
<th>Example</th>
<th>Carrier</th>
<th>Carrier treatment</th>
<th>Cocatalys</th>
<th>Amount of cocatalyst</th>
<th>Zr w-%</th>
<th>mCat</th>
<th>Yield of polymer (g)</th>
<th>Activity kgPE/ g cat x h</th>
<th>Activity kgPE/g Zr x h</th>
<th>butene ml</th>
<th>butene content w-%</th>
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<td>Comparison</td>
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<td>40 kg PP/g x Zr x h</td>
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*) HIBAO formula
Some conclusions from the examples of this patent application:

1. Effect of the carrier:
From examples 1, 15 and 11 can be seen the effect of alumina structure on the catalyst: When silica is used as a carrier the catalyst activity is very poor (example 11). When alumina (example 1) or silica-alumina (example 15) are used the catalyst activity is improved 20 times (all other components are kept constant).

2. Effect of the TMA (= trimethylaluminium) treatment of alumina:
From examples 1 and 14 the effect of TMA can be easily seen. When no TMA is used for alumina treatment the catalyst performance is bad (example 14). When TMA treatment is made (example 1) the activity is increased from 0.02 kgPE/g*cat*h up to 0.7 kgPE/g*cat*h. Actually, the catalyst activity increase is 35 times.

3. Effect of the cocatalyst HIBAO (= hexaisobutylaluminiumoxane)
From examples 1 and 12 the indispensability of the HIBAO can be seen. When no hexaisobutylaluminiumoxane is used, the catalyst activity is very poor being only 0.04 kgPE/g*cat.*h (example 12). The corresponding activity with cocatalyst was 0.7 kgPE/g*cat*h. Actual activity increase in this case is 18 times.

According these claims 1, 2, 3 it is evident that for having active catalyst without MAO as a cocatalyst or coactivator we will need at least all these three components: alumina structure (as a pure alumina or alumina cover like in example 15), TMA-treatment is vital to have catalyst active and finally HIBAO as an external (or internal) cocatalyst.

4. Effect of the amount of HIBAO as a cocatalyst
From examples 3, 4, 5, and 6 the effect of amount of HIBAO can be seen. By increasing the amount of HIBAO the catalyst activity is also increased from 1.2 kgPE/g*cat*h up to 2.7 kgPE/g*cat*h by increasing Al/Zr-ratio from 30 up to 120. When enough cocatalyst is introduced into system, no more activity increase can be seen (examples 5 and 6).

5. Incorporation of a comonomer:
Incorporation of a comonomer (butene) has been studied with examples 7, 8, 9, and 10. By increasing comonomer content at polymerization media, the catalyst activity can be increased and comonomer content increased at polymer. The observed
activity increase was from 1.14 kg up to 2.2 kgLLD-PE when comonomer content was increased from 20 ml up to 80 ml. Also, the comonomer content at polymer back bone was increased from 1.5 up to 4.6 w-%.

5 6. Effect of the amount of metallocene
From examples 1 and 2 can be seen that by increasing amount of metallocene the catalyst activity was increased from 0.7 kgPE up to 2.0 kgPE when Zr content was increased from 0.25 up to 0.5 w-% accordingly.
Claims

1. A process for the preparation of a supported olefin polymerization catalyst composition, comprising a support, a metallocene, and an aluminoxide, characterized by contacting a support comprising a solid compound which is one of pure aluminium oxide, a mixed aluminium oxide such as alumina-silica, an aluminium salt, a magnesium halide, or a C₁-C₈ alkoxy magnesium halide, in any order with at least
a) an organometallic compound of the general formula (1):

\[ R_\{1\} \text{MeXV-1} \]  

(1)

wherein each R is the same or different and is a C₁-C₁₀ alkyl group; M is a metal of Group 1, 2, 12 or 13 of the Periodic Table; each X is the same or different and one of a halogen atom, a hydrogen atom, a hydroxyl radical or a C₁-C₈ hydrocarbyloxy group; l is 1, 2 or 3; v is the oxidation number of the metal M,

b) a metallocene of the general formula (2):

\[ (\text{CpYe})_m \text{M′X′}_n \text{Z}_0 \]  

(2)

wherein each CpYe is the same or different and is one of a mono- or polysubstituted, fused or non-fused, homo- or heterocyclic cyclopentadienyl, indenyl, tetrahydroindenyl, fluorenyl, or octahydrofluorenyl ligand, which ligand is substituted at its cyclopentadienyl ring with at least one substituent Y which is one of a -OR′, -SR′, -NR′₂, -C(H or R′)=, or -PR′₂ radical, each R′ being the same or different and being one of a C₁-C₁₆ hydrocarbyl group, a tri-C₁-C₈ hydrocarbylsilyl group or a tri-C₁-C₈ hydrocarbyloxy silyl group; M′ is a transition metal of Group 4 of the Periodic Table and bound to the ligand CpYe at least in an η₅ bonding mode; each X′ is the same or different and is one of a hydrogen atom, a halogen atom, a C₁-C₈ hydrocarbyl group, a C₁-C₈ hydrocarbylheteroatom group or a tri-C₁-C₈ hydrocarbyl silyl group or two X′ form a ring with each other; Z is a bridge atom or group between two CpYe ligands or one CpYe ligand and the transition metal M′; m is 1 or 2; o is 0 or 1; and n is 4-m if there is no bridge Z or Z is a bridge between two CpYe ligandes, or n is 4-m-o if Z is a bridge between one CpYe ligand and the transition metal M′, and

c) an aluminoxide of one of the following formulas (3):
wherein each \( R' \) and each \( R'' \) is the same or different and is a \( C_2-C_{10} \) alkyl group; and \( p \) is an integer between 1 and 40, and recovering said supported olefin polymerization catalyst composition.

2. The process according to claim 1, characterized by contacting said support at first with

a) said organometallic compound of the general formula (1), then with
b) said metallocene of the general formula (2), and after that with
c) said aluminoxane of the general formulas (3).

3. The process according to claim 2, characterized by

a₁) contacting said support with a solution of said organometallic compound (1), and removing the supernatant from the contacting product,
b₁) contacting the product of step a₁) with a solution of said metallocene (2), and removing the supernatant from the contacting product,
c₁) contacting the product of step b₁) with a solution of said aluminoxane (3), and removing the supernatant from the contacting product, whereby, preferably, the volume of at least one of said solutions is less than at which a slurry is formed.

4. The process according to claim 1, 2 or 3, characterized in that said solid compound of said support is more acid than silica and preferably has the nature of a Lewis acid.
5. The process according to any of the preceding claims, characterized by using a support comprising aluminium oxide, preferably alumina which has been heated to a temperature of between 100 and 1000 °C.

6. The process according to claim 5, characterized in that the aluminium oxide, preferably the calcined alumina, is in the form of, or is deposited on, particles having a diameter of between 10 and 500 μm, preferably between 20 and 200 μm, and, independently, having a surface area of between 50 and 600 m²/g, preferably between 100 and 500 m²/g.

7. The process according to any of the preceding claims, characterized in that the support is contacted with a liquid comprising a), b) and/or c), the volume of which is less than at which a slurry is formed, preferably less than approximately the volume of the pores of the support.

8. The process according to any of the preceding claims, characterized by contacting said support with
a) said organometallic compound of the general formula (1), which is one of a C₁₋C₁₀ alkyl lithium, a C₁₋C₁₀ dialkyl magnesium, or a C₁₋C₁₀ trialkyl aluminium, and preferably is a C₁₋C₆ trialkyl aluminium.

9. The process according to any of the preceding claims, characterized by contacting said support with
a) said organometallic compound of the general formula (1) immersed or dissolved in a hydrocarbon medium, preferably a C₄₋C₁₀ hydrocarbon medium.

10. The process according to any of the preceding claims, characterized by contacting said support with
a) said organometallic compound of the general formula (1) at a weight ratio between the organometallic compound and the support of between 0.1 and 10, preferably between 0.2 and 2, most preferably between 0.3 and 1.5.

11. The process according to any of the preceding claims, characterized by contacting said support with
b) said metalloocene of the general formula (2), wherein said tri-C₁₋C₈ hydrocarbyl silyl group R' of said substituent Y is a tri-C₁₋C₈ hydrocarbyl silyl group capable of π interaction with said O, S, N, or P atoms of Y, preferably a tri-C₁₋C₈ alkyl silyl group, wherein at least one of the C₁₋C₈ alkyls is a branched C₃-
C₈ alkyl such as isopropyl, isobutyl, sec-butyl, tert-butyl, isoamyl, sec-amyl, or tert-amyl.

12. The process according to any of the preceding claims, characterized by contacting said support with
b) said metallocene of the general formula (2), wherein m is 2, and, preferably, the two Cp ligands are bridged with each other by a bivalent atom or group Z having at least one chain atom which is one of a carbon, silicon, oxygen, sulphur, nitrogen or phosphorus atom, preferably wherein m is 2 and Z is ethylene or silylene.

13. The process according to any of the preceding claims, characterized by contacting said support with
b) said metallocene of the general formula (2), wherein M' is Zr.

14. The process according to any of the preceding claims, characterized by contacting said support with
b) said metallocene of the general formula (2), wherein X' is a halogen atom and/or a C₁-C₈ hydrocarbyl group, preferably chlorine and/or methyl.

15. The process according to any of the preceding claims, characterized by contacting said support with
b) said metallocene of the general formula (2) which has the following structural formula (4)
wherein $Y_1$ and $Y_2$ are the same or different and are one of a hydrogen atom, a halogen atom, an acyl group, an acyloxy group, a $C_1$-$C_{10}$ hydrocarbyl group, an $-OR'$, $-SR'$, $-NR'$, $-C(\text{H or R'})=$, or $-PR'_2$ radical, $R'$ being one of a $C_1$-$C_{16}$ hydrocarbyl group or a tri-$C_1$-$C_8$-hydrocarbylsilyl group, provided that at least one of $Y_1$ and $Y_2$ is one of said $-OR'$, $-SR'$, $-NR'$, $-C(\text{H or R'})=$, or $-PR'_2$ radicals; $Z$ is a bivalent atom or group having at least one chain atom which is one of a carbon, silicon, oxygen, sulphur, nitrogen, or phosphorus atom, preferably 1-4 carbon and/or silicon chain atoms; each $R^V$ is the same or different and is one of a hydrogen atom, a halogen atom, a $C_1$-$C_{10}$ hydrocarbyl group, or a $C_1$-$C_{10}$ hydrocarboxyloxy group or ring constituent, $M'$ is one of Ti, Zr, or Hf; and $X_1$ and $X_2$ are the same or different and are one of a halogen atom and a $C_1$-$C_8$ hydrocarbyl group.

16. The process according to any of claims 10-14, characterized by contacting said support with

b) said metalloocene of the formula (2), said metalloocene being ethylene-bis(2-tert-butyldimethylsiloxyindenyl)zirconium dichloride.

17. The process according to any of the preceding claims, characterized by contacting said support with

b) said metalloocene of the formula (2), said metalloocene being dissolved in a $C_4$-$C_{10}$ hydrocarbon solvent, preferably an aromatic hydrocarbon solvent, most preferably toluene.

18. The process according to any of the preceding claims, characterized by contacting said support with

b) said metalloocene of the formula (2) at a molar to weight ratio between the metalloocene and the support of between 0.001 to 0.50 mmol/g, preferably 0.010 to 0.10 mmol/g, most preferably 0.02 to 0.08 mmol/g.

19. The process according to any of the preceding claims, characterized by contacting said support with

c) an aluminoxane of the formulas (3), wherein said $R''$ is a $C_3$-$C_{10}$ alkyl group, preferably an isopropyl, isobutyl, sec-butyl, tert-butyl, isoamyl, sec-amyl, or tert-amyl group, and, independently, $2 \leq n \leq 12$, preferably $4 \leq n \leq 8$. 

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20. The process according to claim 19, **characterized** by contacting said support with
c) an aluminoxane of the formula (3), which is hexa(isobutylaluminiumoxane).

21. The process according to any of the preceding claims, **characterized** by contacting said support previous to, immediately before, or at the beginning of the olefin polymerization, with
c) an aluminoxane of the formula (3) dissolved or immersed in a hydrocarbon solvent, preferably a C₄-C₁₂ aliphatic hydrocarbon solvent such as hexane.

22. The process according to any of the preceding claims, **characterized** by contacting said support with
a) said organometallic compound of the formula (1), said metallocene of the formula (2), and said aluminoxane of the formula (3), at a molar ratio between the aluminoxane aluminium and the metallocene transition metal M' in the catalyst composition of between 20 and 500, preferably between 30 and 300, most preferably between 40 and 200.

23. A supported olefin polymerization catalyst composition, **characterized** in that it has been prepared according to any of claims 1-22.

24. A process for polymerizing at least one olefin, **characterized** by polymerizing an olefin in the presence of the supported olefin polymerization catalyst composition according to claim 23.
A. CLASSIFICATION OF SUBJECT MATTER
IPC 6 C08F10/00  C08F4/602

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

B. FIELDS SEARCHED
Minimum documentation searched (classification system followed by classification symbols)
IPC 6 C08F

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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*O* document referring to an oral disclosure, use, exhibition or other means
*P* document published prior to the international filing date but later than the priority date claimed

1 Date of the actual completion of the international search
8 May 1998

Name and mailing address of the ISA
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NL - 2280 HV Rijswijk
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X Authorized officer
Fischer, B

Date of mailing of the international search report
03/06/1998

Form PCT/ISA210 (second sheet) (July 1992)
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# INTERNATIONAL SEARCH REPORT

Information on patent family members

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