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(54) Title: PROCESS FOR POLYMERIZING 1-BUTENE AND 1-BUTENE POLYMERS

(57) Abstract: A process for polymerizing 1-butene, optionally with up to 30% by mol of ethylene, propylene or an alpha olefin of formula CH<sub>2</sub>=CHT wherein T is a C<sub>3</sub>-C<sub>10</sub> alkyl group, in the presence of a catalyst system obtainable by contacting a metallocene compound having C<sub>1</sub> symmetry with an alumoxane and/or a compound capable of forming an alkyl metallocene cation.



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## PROCESS FOR POLYMERIZING 1-BUTENE AND 1-BUTENE POLYMERS

The present invention relates to a process for polymerizing 1-butene by using metallocene compounds and to the isotactic polybutene obtained thereby.

1-Butene polymers are well known in the art. In view of their good properties in terms of pressure resistance, creep resistance, and impact strength they have a lot of uses such as the manufacture of pipes to be used in the metal pipe replacement, easy-open packaging and films.

The 1-butene (co)polymers are generally prepared by polymerizing 1-butene in the presence of  $\text{TiCl}_3$  based catalysts components together with diethylaluminum chloride (DEAC) as cocatalyst. In some cases diethyl aluminum iodide (DEAI) is also used in mixtures with DEAC. The polymers obtained, however, generally do not show satisfactory mechanical properties. Furthermore, in view of the low yields obtainable with the  $\text{TiCl}_3$  based catalysts, the 1-Butene polymers prepared with these catalysts have a high content of catalyst residues (generally more than 300 ppm of Ti) which lowers the properties of the polymers making it necessary a deashing step.

1-butene (co)polymers can also be obtained by polymerizing the monomers in the presence of a stereospecific catalyst comprising (A) a solid component comprising a Ti compound and an electron-donor compound supported on  $\text{MgCl}_2$ ; (B) an alkylaluminum compound and, optionally, (C) an external electron-donor compound. A process of this type is disclosed in EP-A-172961 and more recently in WO99/45043.

In *Macromolecules* 1995, 28, 1739-1749 *rac*-dimethylsilylbis(4,5,6,7-tetrahydro-1-indenyl)zirconium dichloride and methylaluminoxane have been used for polymerizing 1-butene, even if the yield of the process is not indicated the molecular weight of the polymer ( $M_n$ ) is very low.

Recently metallocene compounds have been used for producing 1-butene polymers. In *Macromol. Rapid Commun.* 18, 581-589 (1997) *rac* and *meso*-[dimethylsilylenebis(2,3,5-trimethyl-cyclopentadienyl)]zirconium dichloride have been used for the polymerization of 1-butene. The yields of the process and the molecular weight of the obtained polymers are rather low.

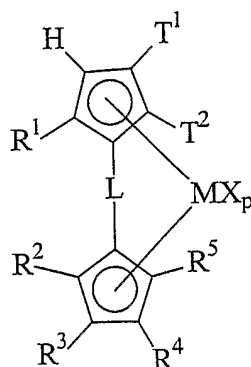
More recently in *Macromolecules* 2000, 33, 1955-1956,  $\text{Me}_2\text{Si}(2\text{-Me-4,5-BzoInd})_2\text{ZrCl}_2$ ,  $\text{Me}_2\text{Si}(2\text{-Me-4-PhInd})_2\text{ZrCl}_2$  and  $\text{Me}_2\text{Si}(\text{Ind})_2\text{ZrCl}_2$  have been tested in the polymerization of 1-butene. Even if the molecular weights of the polymers appear to be quite high, the activities of these catalysts are low as shown in the comparative examples of the present application.

In WO 02/16450 it is described a 1-butene polymer endowed with a low isotacticity. This polymer is obtained by using a specific class of metallocene compounds having a double bridge. With the process of the present invention it is possible to obtain 1-butene polymers having a higher value of isotacticity or that do not meet all the parameters disclosed in this PCT application, by using completely different metallocene compounds.

A new process that permits to obtain 1-butene polymers with high molecular weight and in high yield is therefore desirable.

Thus, according to a first aspect, the present invention relates to a process for polymerizing 1-butene comprising contacting under polymerization conditions 1-butene, optionally from 0 to 30% by mol; preferably from 0 to 10% by mol of ethylene, propylene or an alpha olefin of formula  $\text{CH}_2=\text{CHT}$  wherein T is a  $\text{C}_3\text{-C}_{10}$  alkyl group, in the presence of a catalyst system obtainable by contacting:

(A) a metallocene compounds belonging to the following formula (I):



(I)

wherein:

M is an atom of a transition metal selected from those belonging to group 3, 4, or to the lanthanide or actinide groups in the Periodic Table of the Elements (new IUPAC version); preferably M is zirconium titanium or hafnium;

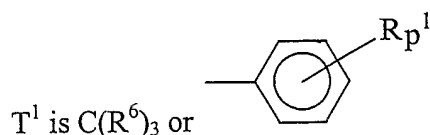
X, equal to or different from each other, is a hydrogen atom, a halogen atom, a R, OR, OR'O,  $\text{OSO}_2\text{CF}_3$ ,  $\text{OCOR}$ , SR,  $\text{NR}_2$  or  $\text{PR}_2$  group wherein R is a linear or branched, saturated or unsaturated  $\text{C}_1\text{-C}_{20}$ -alkyl,  $\text{C}_3\text{-C}_{20}$ -cycloalkyl,  $\text{C}_6\text{-C}_{20}$ -aryl,  $\text{C}_7\text{-C}_{20}$ -alkylaryl or  $\text{C}_7\text{-C}_{20}$ -arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; R' is a  $\text{C}_1\text{-C}_{20}$ -alkylidene,  $\text{C}_6\text{-C}_{20}$ -arylidene,  $\text{C}_7\text{-C}_{20}$ -alkylarylidene, or  $\text{C}_7\text{-C}_{20}$ -arylalkylidene radical; preferably X is a hydrogen

atom, a halogen atom, a OR'O or R group; more preferably X is chlorine or a methyl radical;

p is 1 or 2 being equal to the oxidation state of the metal M minus 2;

R<sup>1</sup> is a hydrogen atom or a linear or branched, saturated or unsaturated C<sub>1</sub>-C<sub>20</sub>-alkyl, C<sub>3</sub>-C<sub>20</sub>-cycloalkyl, C<sub>6</sub>-C<sub>20</sub>-aryl, C<sub>7</sub>-C<sub>20</sub>-alkylaryl, or C<sub>7</sub>-C<sub>20</sub>-arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements;

R<sup>2</sup> with R<sup>3</sup>, and R<sup>4</sup> with R<sup>5</sup>, form a 5 or 6 membered unsaturated rings, preferably said rings are aromatic, optionally said rings contain heteroatoms belonging to groups 13-16 of the Periodic Table of the Elements, and optionally said rings bear alkyl substituents, preferably said alkyl substituents are C<sub>1</sub>-C<sub>10</sub>-alkyl radicals;



wherein R is a linear or branched, saturated or unsaturated C<sub>1</sub>-C<sub>20</sub>-alkyl, C<sub>3</sub>-C<sub>20</sub>-cycloalkyl, C<sub>6</sub>-C<sub>20</sub>-aryl, C<sub>7</sub>-C<sub>20</sub>-alkylaryl, or C<sub>7</sub>-C<sub>20</sub>-arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; p<sup>1</sup> is an integer ranging from 0 to 5; R<sup>6</sup>, equal to or different from each other, are hydrogen atoms or a linear or branched, saturated or unsaturated C<sub>1</sub>-C<sub>20</sub>-alkyl, C<sub>3</sub>-C<sub>20</sub>-cycloalkyl, C<sub>6</sub>-C<sub>20</sub>-aryl, C<sub>7</sub>-C<sub>20</sub>-alkylaryl, or C<sub>7</sub>-C<sub>20</sub>-arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; with the proviso that at least one R<sup>6</sup> is different from hydrogen atom;

T<sup>2</sup> is a hydrogen atom or a linear or branched, saturated or unsaturated C<sub>1</sub>-C<sub>20</sub>-alkyl, C<sub>3</sub>-C<sub>20</sub>-cycloalkyl, C<sub>6</sub>-C<sub>20</sub>-aryl, C<sub>7</sub>-C<sub>20</sub>-alkylaryl, or C<sub>7</sub>-C<sub>20</sub>-arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements;

or T<sup>1</sup> and T<sup>2</sup> can also join to form a saturated or unsaturated, condensed 5 or 6 membered ring optionally containing heteroatoms belonging to groups 13-16 of the Periodic Table of the Elements; said ring can be substituted, preferably the substituents are C<sub>1</sub>-C<sub>20</sub> alkyl groups optionally containing heteroatoms belonging to groups 13-16 of the Periodic Table of the Elements; to form for example a condensed benzene ring; a condensed thiophene ring; a condensed pyrrole ring;

L is a divalent bridging group selected from the group consisting of  $\text{CR}^7_2$ ,  $\text{SiR}^7_2$ ,  $(\text{CR}^7_2)_2$  and  $(\text{SiR}^7_2)_2$  radicals, wherein  $\text{R}^7$ , equal to or different from each other, are hydrogen atoms or a linear or branched, saturated or unsaturated  $\text{C}_1$ - $\text{C}_{20}$ -alkyl,  $\text{C}_3$ - $\text{C}_{20}$ -cycloalkyl,  $\text{C}_6$ - $\text{C}_{20}$ -aryl,  $\text{C}_7$ - $\text{C}_{20}$ -alkylaryl, or  $\text{C}_7$ - $\text{C}_{20}$ -arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; optionally two  $\text{R}^7$  groups can also form an aliphatic ring having 3 to 8 atoms which can bear alkyl substituents, preferably said alkyl substituents are  $\text{C}_1$ - $\text{C}_{10}$ -alkyl radicals; L is preferably  $\text{CR}^7_2$  or  $\text{SiR}^7_2$ ; preferably  $\text{R}^7$  is a hydrogen atom or a methyl or phenyl radical; more preferably L is  $\text{Si}(\text{CH}_3)_2$  or  $\text{C}(\text{CH}_3)_2$ ;

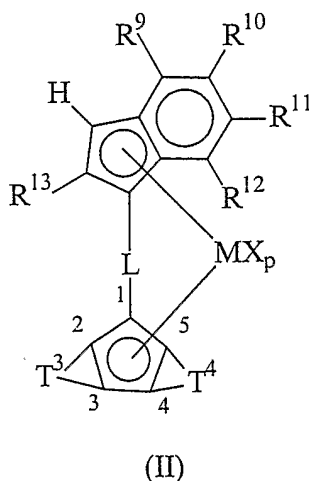
- (B) an alumoxane or a compound capable of forming an alkyl metallocene cation; and optionally
- (C) an organo aluminum compound.

Non limiting examples of rings formed by  $\text{R}^2$  and  $\text{R}^3$  or  $\text{R}^4$  and  $\text{R}^5$  are condensed benzene rings; condensed thiophene rings; and condensed pyrrole rings;

Preferred metallocene compounds of formula (I) belongs to the following three classes (1), (2) and (3) and have respectively formula (II), (III) and (IV).

#### Class (1)

Metallocene compounds belonging to class (1) have the following formula (II)



wherein:

L, M, X and p have the same meaning as described above;

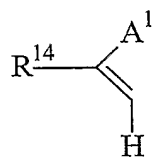
$\text{R}^{13}$  is a hydrogen atom or a linear or branched, saturated or unsaturated  $\text{C}_1$ - $\text{C}_{20}$ -alkyl,

C<sub>3</sub>-C<sub>20</sub>-cycloalkyl, C<sub>6</sub>-C<sub>20</sub>-aryl, C<sub>7</sub>-C<sub>20</sub>-alkylaryl, or C<sub>7</sub>-C<sub>20</sub>-arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; preferably R<sup>13</sup> is a linear or branched C<sub>1</sub>-C<sub>20</sub> alkyl radical; more preferably R<sup>13</sup> is a methyl or an ethyl radical;

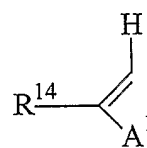
R<sup>9</sup>, R<sup>10</sup>, R<sup>11</sup> and R<sup>12</sup> are hydrogen atoms or linear or branched, saturated or unsaturated C<sub>1</sub>-C<sub>20</sub>-alkyl, C<sub>3</sub>-C<sub>20</sub>-cycloalkyl, C<sub>6</sub>-C<sub>20</sub>-aryl, C<sub>7</sub>-C<sub>20</sub>-alkylaryl, or C<sub>7</sub>-C<sub>20</sub>-arylalkyl radicals, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; R<sup>9</sup>, R<sup>10</sup>, R<sup>11</sup> and R<sup>12</sup> can also form one or more 5 or 6 membered saturated or unsaturated rings optionally containing heteroatoms belonging to groups 13-16 of the Periodic Table of the Elements, said rings can bear alkyl substituents;

preferably R<sup>9</sup> is selected from the group consisting of C<sub>1</sub>-C<sub>20</sub> alkyl and C<sub>6</sub>-C<sub>20</sub> aryl radicals, even more preferably R<sup>9</sup> is a methyl, tertbutyl, isopropyl, phenyl, alkyl substituted phenyl radical; preferably said alkyl substituents are C<sub>1</sub>-C<sub>10</sub>-alkyl radicals; preferably R<sup>10</sup>, R<sup>11</sup> and R<sup>12</sup> are hydrogen atoms;

T<sup>3</sup> and T<sup>4</sup> are moieties of formula (IIa) or (IIb):



(IIa)



(IIb)

wherein:

when T<sup>3</sup> and T<sup>4</sup> are moieties of formula (IIa) A<sup>1</sup> bonds to the cyclopentadienyl group in position 2 and 5;

when T<sup>3</sup> and T<sup>4</sup> are moieties of formula (IIb) A<sup>1</sup> bonds to the cyclopentadienyl group in position 3 and 4;

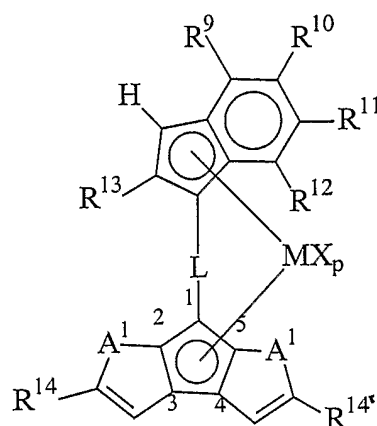
A<sup>1</sup> is a sulphur atom (S), a oxygen atom (O), or a NR, PR, or CR<sup>15</sup> group; wherein R is a linear or branched, saturated or unsaturated C<sub>1</sub>-C<sub>20</sub>-alkyl, C<sub>3</sub>-C<sub>20</sub>-cycloalkyl, C<sub>6</sub>-C<sub>20</sub>-aryl, C<sub>7</sub>-C<sub>20</sub>-alkylaryl, or C<sub>7</sub>-C<sub>20</sub>-arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; and R<sup>15</sup> is a hydrogen atom or a linear or branched, saturated or unsaturated C<sub>1</sub>-C<sub>20</sub>-alkyl, C<sub>3</sub>-C<sub>20</sub>-cycloalkyl, C<sub>6</sub>-C<sub>20</sub>-aryl, C<sub>7</sub>-C<sub>20</sub>-alkylaryl, or C<sub>7</sub>-C<sub>20</sub>-arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; preferably in the moiety (IIa) A<sup>1</sup> is sulfur and in the moiety (IIb) A<sup>1</sup> is NR; preferably the group NR is N-methyl, N-ethyl or N-phenyl

radical; preferably  $R^{15}$  is a hydrogen atom;

$R^{14}$  is a hydrogen atom or a linear or branched, saturated or unsaturated  $C_1$ - $C_{20}$ -alkyl,  $C_3$ - $C_{20}$ -cycloalkyl,  $C_6$ - $C_{20}$ -aryl,  $C_7$ - $C_{20}$ -alkylaryl, or  $C_7$ - $C_{20}$ -arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; preferably  $R^{14}$  is a  $C_1$ - $C_{20}$  alkyl radical; more preferably  $R^{14}$  is a methyl radical;

preferably  $T^3$  and  $T^4$  are moieties of formula (IIa);

preferred compounds of formula (II) has formula (IIc)

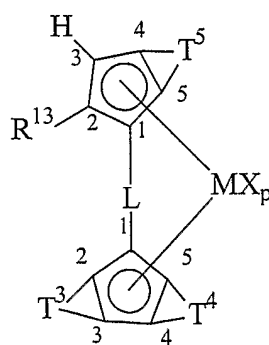


(IIc)

wherein  $R^9$ ,  $R^{10}$ ,  $R^{11}$ ,  $R^{12}$ ,  $R^{13}$ ,  $R^{14}$ ,  $A^1$ ,  $L$ ,  $M$ ,  $X$ , and  $p$  have the same meaning as described above.

## Class (2)

Metallocene compounds belonging to class (2) have the following formula (III)

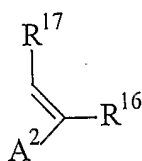


(III)

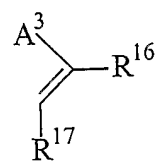
wherein:

$T^3$ ,  $T^4$ ,  $R^{13}$ ,  $M$ ,  $X$ ,  $p$  and  $L$  have the same meaning as described above;

$T^5$  is a moiety of formula (IIIa) or (IIIb)



(IIIa)



(IIIb)

wherein:

in the moiety of formula (IIIa)  $A^2$  bonds to the cyclopentadienyl group in position 5; in the moiety of formula (IIIb)  $A^3$  bonds to the cyclopentadienyl group in position 4;

$A^2$  is a sulfur atom (S), an oxygen atom (O), or a  $CR^{15}$  group; wherein  $R^{15}$  is defined as above; preferably  $A^2$  is a sulphur atom;

$R^{16}$  is a hydrogen atom or a linear or branched, saturated or unsaturated  $C_1$ - $C_{20}$ -alkyl,  $C_3$ - $C_{20}$ -cycloalkyl,  $C_6$ - $C_{20}$ -aryl,  $C_7$ - $C_{20}$ -alkylaryl, or  $C_7$ - $C_{20}$ -arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; preferably  $R^{16}$  is a  $C_1$ - $C_{20}$  alkyl radical; more preferably  $R^{16}$  is a methyl radical;

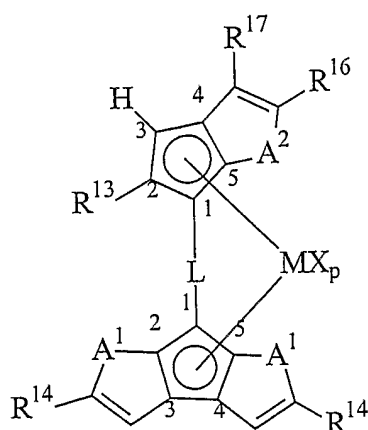
$R^{17}$  is a linear or branched, saturated or unsaturated  $C_1$ - $C_{20}$ -alkyl,  $C_3$ - $C_{20}$ -cycloalkyl,  $C_6$ - $C_{20}$ -aryl,  $C_7$ - $C_{20}$ -alkylaryl, or  $C_7$ - $C_{20}$ -arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements;  $R^{17}$  and  $R^{16}$  can also join to form a 5 or 6 membered aliphatic or aromatic ring; said ring can bear alkyl substituents, preferably said alkyl substituents are  $C_1$ - $C_{10}$ -alkyl radicals;

preferably  $R^{17}$  is a  $C_1$ - $C_{20}$  alkyl or  $C_6$ - $C_{20}$  alkylaryl radical; more preferably  $R^{17}$  is phenyl radical substituted with one or more  $C_1$ - $C_{20}$  alkyl radical; preferably the substitution is in position 2 or 2 and 4 with respect to the phenyl ring;

$A^3$  is a  $NR$  group or a  $CR^{15}$  group wherein  $R$  is a linear or branched, saturated or unsaturated  $C_1$ - $C_{20}$ -alkyl,  $C_3$ - $C_{20}$ -cycloalkyl,  $C_6$ - $C_{20}$ -aryl,  $C_7$ - $C_{20}$ -alkylaryl, or  $C_7$ - $C_{20}$ -arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; and  $R^{15}$  is defined as above; preferably  $A^3$  is a  $NR$  group; more preferably  $A^3$  is a  $N$ -methyl or  $N$ -phenyl group.

Particularly preferred are those compounds wherein  $T^5$  is a moiety of formula (IIIa) and  $T^3$  and  $T^4$  are moieties of formula (IIa) to form a compound of formula (IIIc)



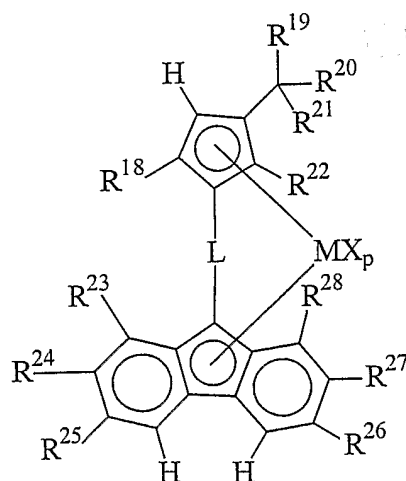


(IIIc)

wherein  $R^{13}$ ,  $R^{14}$ ,  $R^{16}$ ,  $R^{17}$ ,  $A^1$ ,  $A^2$ ,  $L$ ,  $M$ ,  $X$ , and  $p$  have been described above.

### Class (3)

Metallocene compounds belonging to class (3) have the following formula (IV)



(IV)

Wherein  $M$ ,  $L$ ,  $X$  and  $p$  have the same meaning as described above;

$R^{18}$ ,  $R^{22}$ ,  $R^{23}$ ,  $R^{24}$ ,  $R^{25}$ ,  $R^{26}$ ,  $R^{27}$  and  $R^{28}$  are hydrogen atoms or a linear or branched, saturated or unsaturated  $C_1$ - $C_{20}$ -alkyl,  $C_3$ - $C_{20}$ -cycloalkyl,  $C_6$ - $C_{20}$ -aryl,  $C_7$ - $C_{20}$ -alkylaryl, or  $C_7$ - $C_{20}$ -arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; or two or more adjacent  $R^{23}$ ,  $R^{24}$ ,  $R^{25}$ ,  $R^{26}$ ,  $R^{27}$ , and  $R^{28}$  can form one or more aliphatic or aromatic  $C_4$ - $C_8$  rings that can bear alkyl substituents, preferably said alkyl substituents are  $C_1$ - $C_{10}$ -alkyl radicals;

$R^{19}$ ,  $R^{20}$  and  $R^{21}$  are hydrogen atoms or a linear or branched, saturated or unsaturated

C<sub>1</sub>-C<sub>20</sub>-alkyl, C<sub>3</sub>-C<sub>20</sub>-cycloalkyl, C<sub>6</sub>-C<sub>20</sub>-aryl, C<sub>7</sub>-C<sub>20</sub>-alkylaryl, or C<sub>7</sub>-C<sub>20</sub>-arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; with the proviso that at least one R<sup>19</sup>, R<sup>20</sup> and R<sup>21</sup> is different from a hydrogen atom;

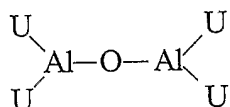
Preferably in the compounds of formula (IV) R<sup>22</sup>, R<sup>23</sup>, R<sup>24</sup>, R<sup>25</sup>, R<sup>26</sup>, R<sup>27</sup> and R<sup>28</sup> are hydrogen atoms; R<sup>18</sup> is a hydrogen atom or a C<sub>1</sub>-C<sub>20</sub> alkyl radical; R<sup>19</sup>, R<sup>20</sup>, R<sup>21</sup> are a C<sub>1</sub>-C<sub>20</sub> alkyl radical; more preferably they are methyl groups.

Metallocene compounds of formula (I) are well known in the art. In particular compounds of class (1) and (2) have been described in WO 01/47939; compounds belonging to class (3) have been described in EP 537 130.

Alumoxanes used as component B) can be obtained by reacting water with an organo-aluminium compound of formula H<sub>j</sub>AlU<sub>3-j</sub> or H<sub>j</sub>Al<sub>2</sub>U<sub>6-j</sub>, where U substituents, same or different, are hydrogen atoms, halogen atoms, C<sub>1</sub>-C<sub>20</sub>-alkyl, C<sub>3</sub>-C<sub>20</sub>-cycloalkyl, C<sub>6</sub>-C<sub>20</sub>-aryl, C<sub>7</sub>-C<sub>20</sub>-alkylaryl or or C<sub>7</sub>-C<sub>20</sub>-arylalkyl radical, optionally containing silicon or germanium atoms with the proviso that at least one U is different from halogen, and j ranges from 0 to 1, being also a non-integer number. In this reaction the molar ratio of Al/water is preferably comprised between 1:1 and 100:1.

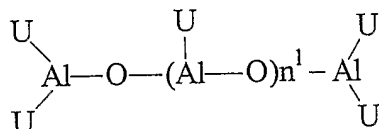
The molar ratio between aluminium and the metal of the metallocene generally is comprised between about 10:1 and about 20000:1, and more preferably between about 100:1 and about 5000:1.

The alumoxanes used in the catalyst according to the invention are considered to be linear, branched or cyclic compounds containing at least one group of the type:

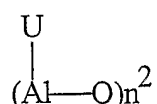


wherein the substituents U, same or different, are described above.

In particular, alumoxanes of the formula:



can be used in the case of linear compounds, wherein n<sup>1</sup> is 0 or an integer from 1 to 40 and the substituents U are defined as above, or alumoxanes of the formula:



can be used in the case of cyclic compounds, wherein  $n^2$  is an integer from 2 to 40 and the U substituents are defined as above.

Examples of alumoxanes suitable for use according to the present invention are methylalumoxane (MAO), tetra-(isobutyl)alumoxane (TIBAO), tetra-(2,4,4-trimethyl-pentyl)alumoxane (TIOAO), tetra-(2,3-dimethylbutyl)alumoxane (TDMBAO) and tetra-(2,3,3-trimethylbutyl)alumoxane (TTMBAO).

Particularly interesting cocatalysts are those described in WO 99/21899 and in WO01/21674 in which the alkyl and aryl groups have specific branched patterns.

Non-limiting examples of aluminium compounds according to WO 99/21899 and WO01/21674 are:

tris(2,3,3-trimethyl-butyl)aluminium, tris(2,3-dimethyl-hexyl)aluminium, tris(2,3-dimethyl-butyl)aluminium, tris(2,3-dimethyl-pentyl)aluminium, tris(2,3-dimethyl-heptyl)aluminium, tris(2-methyl-3-ethyl-pentyl)aluminium, tris(2-methyl-3-ethyl-hexyl)aluminium, tris(2-methyl-3-ethyl-heptyl)aluminium, tris(2-methyl-3-propyl-hexyl)aluminium, tris(2-ethyl-3-methyl-butyl)aluminium, tris(2-ethyl-3-methyl-pentyl)aluminium, tris(2,3-diethyl-pentyl)aluminium, tris(2-propyl-3-methyl-butyl)aluminium, tris(2-isopropyl-3-methyl-butyl)aluminium, tris(2-isobutyl-3-methyl-pentyl)aluminium, tris(2,3,3-trimethyl-pentyl)aluminium, tris(2,3,3-trimethyl-hexyl)aluminium, tris(2-ethyl-3,3-dimethyl-butyl)aluminium, tris(2-ethyl-3,3-dimethyl-pentyl)aluminium, tris(2-isopropyl-3,3-dimethyl-butyl)aluminium, tris(2-trimethylsilyl-propyl)aluminium, tris(2-methyl-3-phenyl-butyl)aluminium, tris(2-ethyl-3-phenyl-butyl)aluminium, tris(2,3-dimethyl-3-phenyl-butyl)aluminium, tris(2-phenyl-propyl)aluminium, tris[2-(4-fluoro-phenyl)-propyl]aluminium, tris[2-(4-chloro-phenyl)-propyl]aluminium, tris[2-(3-isopropyl-phenyl)-propyl]aluminium, tris(2-phenyl-butyl)aluminium, tris(3-methyl-2-phenyl-butyl)aluminium, tris(2-phenyl-pentyl)aluminium, tris[2-(pentafluorophenyl)-propyl]aluminium, tris[2,2-diphenyl-ethyl]aluminium and tris[2-phenyl-2-methyl-propyl]aluminium, as well as the corresponding compounds wherein one of the hydrocarbyl groups is replaced with a hydrogen atom, and those wherein one or two of the hydrocarbyl groups are replaced with an isobutyl group.

Amongst the above aluminium compounds, trimethylaluminium (TMA), triisobutylaluminium (TIBAL), tris(2,4,4-trimethyl-pentyl)aluminium (TIOA), tris(2,3-dimethylbutyl)aluminium

(TDMBA) and tris(2,3,3-trimethylbutyl)aluminium (TTMBA) are preferred.

Non-limiting examples of compounds able to form an alkylmetallocene cation are compounds of formula  $D^+E^-$ , wherein  $D^+$  is a Brønsted acid, able to donate a proton and to react irreversibly with a substituent X of the metallocene of formula (I) and  $E^-$  is a compatible anion, which is able to stabilize the active catalytic species originating from the reaction of the two compounds, and which is sufficiently labile to be able to be removed by an olefinic monomer. Preferably, the anion  $E^-$  comprises of one or more boron atoms. More preferably, the anion  $E^-$  is an anion of the formula  $BAr_4^{(-)}$ , wherein the substituents Ar which can be identical or different are aryl radicals such as phenyl, pentafluorophenyl or bis(trifluoromethyl)phenyl. Tetrakis-pentafluorophenyl borate is particularly preferred examples of these compounds are described in WO 91/02012. Moreover, compounds of the formula  $BAr_3$  can conveniently be used. Compounds of this type are described, for example, in the published International patent application WO 92/00333. Other examples of compounds able to form an alkylmetallocene cation are compounds of formula  $BAr_3P$  wherein P is a substituted or unsubstituted pyrrol radicals. . These compounds are described in WO01/62764. Other examples of cocatalyst can be found in EP 775707 and DE 19917985. Compounds containing boron atoms can be conveniently supported according to the description of DE-A-19962814 and DE-A-19962910. All these compounds containing boron atoms can be used in a molar ratio between boron and the metal of the metallocene comprised between about 1:1 and about 10:1; preferably 1:1 and 2:1; more preferably about 1:1.

Non limiting examples of compounds of formula  $D^+E^-$  are:

Triethylammoniumtetra(phenyl)borate,  
 Tributylammoniumtetra(phenyl)borate,  
 Trimethylammoniumtetra(tolyl)borate,  
 Tributylammoniumtetra(tolyl)borate,  
 Tributylammoniumtetra(pentafluorophenyl)borate,  
 Tributylammoniumtetra(pentafluorophenyl)aluminate,  
 Tripropylammoniumtetra(dimethylphenyl)borate,  
 Tributylammoniumtetra(trifluoromethylphenyl)borate,  
 Tributylammoniumtetra(4-fluorophenyl)borate,  
 N,N-Dimethylaniliniumtetra(phenyl)borate,  
 N,N-Diethylaniliniumtetra(phenyl)borate,  
 N,N-Dimethylaniliniumtetrakis(pentafluorophenyl)borate,  
 N,N-Dimethylaniliniumtetrakis(pentafluorophenyl)aluminate,

Di(propyl)ammoniumtetrakis(pentafluorophenyl)borate,  
 Di(cyclohexyl)ammoniumtetrakis(pentafluorophenyl)borate,  
 Triphenylphosphoniumtetrakis(phenyl)borate,  
 Triethylphosphoniumtetrakis(phenyl)borate,  
 Diphenylphosphoniumtetrakis(phenyl)borate,  
 Tri(methylphenyl)phosphoniumtetrakis(phenyl)borate,  
 Tri(dimethylphenyl)phosphoniumtetrakis(phenyl)borate,  
 Triphenylcarbeniumtetrakis(pentafluorophenyl)borate,  
 Triphenylcarbeniumtetrakis(pentafluorophenyl)aluminate,  
 Triphenylcarbeniumtetrakis(phenyl)aluminate,  
 Ferroceniumtetrakis(pentafluorophenyl)borate,  
 Ferroceniumtetrakis(pentafluorophenyl)aluminate.  
 Triphenylcarbeniumtetrakis(pentafluorophenyl)borate,  
 N,N-Dimethylaniliniumtetrakis(pentafluorophenyl)borate.

Organic aluminum compounds used as compound C) are those of formula  $H_jAlU_{3-j}$  or  $H_jAl_2U_{6-j}$  described above.

The catalysts of the present invention can also be supported on an inert carrier. This is achieved by depositing the metallocene compound A) or the product of the reaction thereof with the component B), or the component B) and then the metallocene compound A) on an inert support such as, for example, silica, alumina, Al-Si, Al-Mg mixed oxides, magnesium halides, styrene/divinylbenzene copolymers, polyethylene or polypropylene. The supportation process is carried out in an inert solvent such as hydrocarbon for example toluene, hexane, pentane or propane and at a temperature ranging from 0°C to 100°C, preferably the process is carried out at a temperature ranging from 25°C to 90°C or the process is carried out at room temperature.

A suitable class of supports which can be used is that constituted by porous organic supports functionalized with groups having active hydrogen atoms. Particularly suitable are those in which the organic support is a partially crosslinked styrene polymer. Supports of this type are described in European application EP-633272.

Another class of inert supports particularly suitable for use according to the invention is that of polyolefin porous prepolymers, particularly polyethylene.

A further suitable class of inert supports for use according to the invention is that of porous magnesium halides such as those described in International application WO 95/32995.

The solid compound thus obtained, in combination with the further addition of the alkylaluminium compound either as such or prereacted with water if necessary, can be usefully employed in the gas-phase polymerization.

With the process of the present invention it is possible to obtain a 1-butene polymer having high molecular weight and in high yields.

Another object of the present invention is a 1-butene homopolymer obtainable with the process of the present invention in particular when compounds of class 1 or 2 are used, having the following characteristics:

- $65 < \text{mm} < 100$ ; preferably  $75 < \text{mm} < 100$ ; even more preferably  $80 < \text{mm} < 100$ ;
- intrinsic viscosity (I.V.)  $> 0.45$ ; preferably  $\geq 0.5$ ; more preferably  $> 0.7$ .
- 4,1 insertions (regioerrors)  $< 0.19\%$ ; preferably  $< 0.1\%$ ;
- an extractable content in boiling diethylether  $< 2\%$ ; preferably  $< 1\%$ .

Preferably the 1-butene homopolymer of the present invention does not have 4,1 insertions (regioerrors) detectable with a 400 MHz spectrometer operating at 100.61 MHz. Preferably the 1-butene homopolymer of the present invention has isotactic pentads (mmmm)  $\geq 90\%$  more preferably  $\geq 93\%$ .

More preferably the 1-butene homopolymer of the present invention does not have extractable content in boiling diethylether.

Furthermore the 1-butene homopolymer object of the present invention satisfies the following formula:

$$(\text{mmmm}) > 90 - 2 \times \text{rr}$$

wherein

mmmm is the value of the isotactic pentads and rr is the value of the syndiotactic triads calculated with 400 MHz spectrometer operating at 100.61 MHz.

Furthermore the 1-butene homopolymers of the present invention are endowed with a flexural modulus value (ASTM D-790) comprised between 150 and 300 Mpa. This value of the modulus in conjunction with the relatively high melting point render the 1-butene homopolymers of the present invention useful for advantageously replacing the 1-butene copolymers that at equivalent melting point show a lower flexural modulus.

The polymerization process of the present invention can be carried out in liquid phase, optionally in the presence of an inert hydrocarbon solvent, or in gas phase. Said hydrocarbon solvent can be either aromatic (such as toluene) or aliphatic (such as propane, hexane, heptane,

isobutane, cyclohexane and 2,2,4-trimethylpentane).

The polymerization temperature preferably ranges from 0°C to 250°C; preferably comprised between 20°C and 150°C and, more particularly between 40°C and 90°C;

Generally, the polymers of the present invention are endowed with a narrow molecular weight distribution. The molecular weight distribution is represented by the ratio  $M_w/M_n$  which, for the polymers of the present invention, when the metallocene used is a pure isomer, is generally lower than 4, preferably lower than 3.5 and, more preferably, lower than 3.

The molecular weight distribution can be varied by using mixtures of different metallocene compounds or by carrying out the polymerization in several stages which differ as to the polymerization temperature and/or the concentrations of the molecular weight regulators and/or the monomers concentration. Moreover by carrying out the polymerization process by using a combination of two different metallocene compounds of formula (I) a polymer endowed with a broad melting is produced.

The polymerization yield depends on the purity of the transition metal organometallic catalyst compound (A) in the catalyst, therefore, said compound can be used as such or can be subjected to purification treatments before use.

The following examples are for illustrative purpose and do not intend to limit the scope of the invention.

## EXAMPLES

### Experimental section

The intrinsic viscosity (I.V.) was measured in tetrahydronaphthalene (THN) at 135°C.

The melting points of the polymers ( $T_m$ ) were measured by Differential Scanning Calorimetry (D.S.C.) on an Perkin Elmer DSC-7 instrument, according to the standard method. A weighted sample (5-10 mg) obtained from the polymerization was sealed into aluminum pans and heated at 200°C with a scanning speed corresponding to 20°C/minute. The sample was kept at 200°C for 5 minutes to allow a complete melting of all the crystallites. Successively, after cooling to 0°C with a scanning speed corresponding to 20°C/minute, the peak temperature was taken as crystallization temperature ( $T_c$ ). After standing 5 minutes at 0°C, the sample was heated for the second time at 200°C with a scanning speed corresponding to 20°C/min. In this second heating run, the peak temperature was taken as the melting temperature ( $T_m$ ) and the area as global melting enthalpy ( $\Delta H_f$ ).

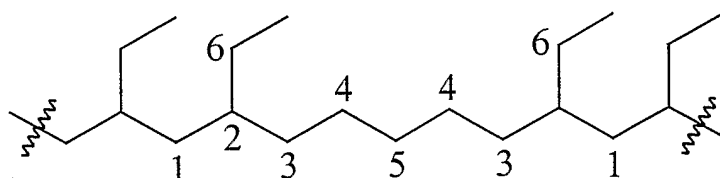
The molecular weight distribution was determined on a WATERS 150 C using the following

chromatographic conditions:

Columns: 3x SHODEX AT 806 MS; 1x SHODEX UT 807; 1x SHODEX AT-G;  
 Solvent: 1,2,4 trichlorobenzene (+ 0.025% 2,6-Di-tert.Butyl-4-Methyl-Phenol);  
 Flow rate: 0.6 - 1 ml/min;  
 Temperature: 135 °C;  
 Detector: INFRARED AT  $\lambda \approx 3.5 \mu\text{m}$ ;  
 Calibration: Universal Calibration with PS-Standards.

$^{13}\text{C}$ -NMR spectra were acquired on a DPX-400 spectrometer operating at 100.61 MHz in the Fourier transform mode at 120 °C. The peak of the 2B<sub>2</sub> carbon (nomenclature according to Carman, C. J.; Harrington, R. A.; Wilkes, C. E. *Macromolecules* **1977**, *10*, 535) was used as internal reference at 27.73. The samples were dissolved in 1,1,2,2-tetrachloroethane-*d*<sub>2</sub> at 120 °C with a 8% wt/v concentration. Each spectrum was acquired with a 90° pulse, 15 seconds of delay between pulses and CPD (waltz16) to remove 1H-13C coupling. About 3000 transients were stored in 32K data points using a spectral window of 6000 Hz. Assignments of 4,1 insertion were made according to Busico (V. Busico, R. Cipullo, A. Borriello, *Macromol. Rapid. Commun.* **1995**, *16*, 269-274)

The content of 4,1 insertions was calculated as follows: 4,1 units =  $0.5 \times I_4 \times 100 / (I_2 + I_4)$



#### 4,1-sequence

#### Preparation of catalyst components

isopropylidene(3-tertbutyl-1-cyclopentadienyl)(9-fluorenyl) zirconium dichloride (A-1) was prepared according to EP 537130. Dimethylsilyl{(1-indenyl)-7-(2,5-dimethyl-cyclopenta[1,2-b:4,3-b']-dithiophene)} zirconium dichloride (A-2); dimethylsilyl{(2-methyl-1-indenyl)-7-(2,5-dimethyl-cyclopenta[1,2-b:4,3-b']-dithiophene)} zirconium dichloride (A-3) and dimethylsilyl{(2-methylcyclopenta[a]naphthalene)-7-(2,5-dimethylcyclopenta[1,2-b:4,3-b']-dithiophene)} zirconium dichloride (A-4) were prepared according to PCT/EP00/13191. rac dimethylsilylbis(2-methyl-4-phenyl-indenyl) zirconium dichloride (A-5) was prepared



according to USP 5,786,432. rac dimethylsilylbis(2-methyl-4-5-benzoindeny) zirconium dichloride (A-6) was prepared according to USP 5,932,669.

The cocatalyst methylalumoxane (MAO) was a commercial product which was used as received (Witco AG, 10 %wt/vol toluene solution, 1.7 M in Al).

#### **Polymerization examples 1-4 and comparative examples 5-6**

The cocatalyst methylalumoxane (MAO) was a commercial product which was used as received (Witco AG, 10 %wt/vol toluene solution, 1.7 M in Al). The catalyst mixture was prepared by dissolving the desired amount of the metallocene with the proper amount of the MAO solution, (Al/Zr ratio = 1000) obtaining a solution which was stirred for 10 min at ambient temperature before being injected into the autoclave.

#### **Polymerization (general procedure)**

4 mmol of  $\text{Al}(i\text{-Bu})_3$  (as a 1M solution in hexane) and 712 g of 1-butene were charged at room temperature in a 2.5-L jacketed stainless-steel autoclave, equipped with magnetically driven stirrer and a 35-mL stainless-steel vial, connected to a thermostat for temperature control, previously purified by washing with an  $\text{Al}(i\text{-Bu})_3$  solution in hexanes and dried at 50°C in a stream of nitrogen. The autoclave was then thermostatted at the polymerization temperature, and then the toluene solution containing the catalyst/cocatalyst mixture was injected in the autoclave by means of nitrogen pressure through the stainless-steel vial, and the polymerization carried out at constant temperature for 1 hour. The polymerization was stopped by pressurizing CO into the reactor. After venting the unreacted monomer and cooling the reactor to room temperature, the polymer was dried under reduced pressure at 60 °C.

The polymerization conditions and the characterization data of the obtained polymers are reported in Table 1

#### **Diethyl ether solubles**

Samples of 5 g of 1-butene polymer obtained according to polymerization examples 1-4 was subjected to Soxhlet extraction with diethyl ether for 6 hours. The extracts was evaporated. No residues of polymer were found.

#### **Characterization of the polymer obtained in example 3**

Samples of polymer obtained from example 3 and a 1-butene ethylene copolymer (4.7% by mol of ethylene content) sold by Basell (grade DP – 8310) were ground in an electric mill with liquid nitrogen in order to achieve the right size to feed them in a Brabender® mixer

chamber. The ground samples were mixed in a Brabender<sup>®</sup> chamber with 1% 2,6-di-*t*-butyl-4-methyl phenol (BHT) at 200°C and then transformed in a 4.0 mm thick plaques through compression molding at 200°C.

The 4.0 mm thick plaques were submitted to the flexural modulus determination according to ISO 178 method. The results are reported in table 2. From table 2 clearly results that the commercial copolymer has the same melting point of the polymer obtained in example 3 but a considerably lower Flexural modulus.

Table 1

Ex	metall	mg	Al <sub>(MAO)</sub> /Zr	T <sub>pol</sub>	t (min)	Yield (g)	Activity kg/(g <sub>cat</sub> *h )	I.V. (dL/g)	M <sub>w</sub> /M <sub>n</sub>	T <sub>m</sub> (II) °C	ΔH <sub>f</sub> (II) J/g
1	A-1	4	1000	60	30	46.4	23.2	0.5	n.a.	100	33
2	A-2	4	1000	60	15	79.4	79.4	0.5	2.25	67	36
3	A-3	4	1000	60	60	249.4	62.4	0.9	2.13	77	13
4	A-4	4	1000	60	30	108.5	54.2	0.8	2.56	91	27
5*	A-5	4	1000	60	30	39.5	9.9	0.9	2.12	105	33
6*	A-6	4	1000	60	60	17.5	4.4	1.1	n.a.	n.a.	n.a.

\* comparative; n.d.=not detectable; n.a.=not available

Table 1 (continued)

Ex	mmmm	mm	mmrr + rmmr	rr	90-2rr	regioerrors 4,1 insertions
1	98	98.7	0.9	0	90	n.d.
2	86	91.3	5.8	2.9	84.2	n.d.
3	87	92.2	5.2	2.6	84.8	n.d.
4	94	96.6	2.2	1.1	87.8	n.d.
5*	n.a.	≈100	n.a.	n.a.	n.a.	0.4
6*	n.a.	99.2	n.a.	n.a.	n.a.	1

\* comparative; n.d.=not detectable; n.a.=not available

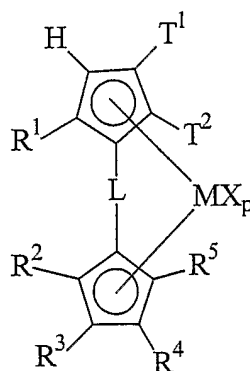
Table 2

Property	DP-8310	Example 3
T <sub>m</sub> (II) (°C)	83.8	84.1
M <sub>w</sub> /M <sub>n</sub>	5.0	2.13
I.V. (dL/g)	1.50	0.9
Flexural modulus (Mpa)	73	250

## CLAIMS

1. A process for polymerizing 1-butene comprising contacting under polymerization conditions 1-butene, optionally from 0 to 30% by mol of ethylene, propylene or an alpha olefin of formula  $\text{CH}_2=\text{CHT}$  wherein T is a  $\text{C}_3\text{-C}_{10}$  alkyl group, in the presence of a catalyst system obtainable by contacting:

(A) a metallocene compound having the following formula (I)



(I)

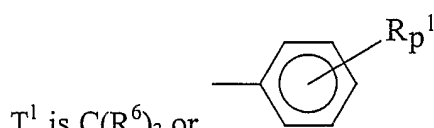
wherein:

X, equal to or different from each other, is a hydrogen atom, a halogen atoms or R, OR, OR'O,  $\text{OSO}_2\text{CF}_3$ ,  $\text{OCOR}$ , SR,  $\text{NR}_2$  or  $\text{PR}_2$  group, wherein R is a linear or branched, saturated or unsaturated  $\text{C}_1\text{-C}_{20}$ -alkyl,  $\text{C}_3\text{-C}_{20}$ -cycloalkyl,  $\text{C}_6\text{-C}_{20}$ -aryl,  $\text{C}_7\text{-C}_{20}$ -alkylaryl or  $\text{C}_7\text{-C}_{20}$ -arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; and the R' is a  $\text{C}_1\text{-C}_{20}$ -alkylidene,  $\text{C}_6\text{-C}_{20}$ -arylidene,  $\text{C}_7\text{-C}_{20}$ -alkylarylidene, or  $\text{C}_7\text{-C}_{20}$ -arylalkylidene radical.

p is 1 or 2 being equal to the oxidation state of the metal M minus 2;

R<sup>1</sup> is a hydrogen atom or a linear or branched, saturated or unsaturated  $\text{C}_1\text{-C}_{20}$ -alkyl,  $\text{C}_3\text{-C}_{20}$ -cycloalkyl,  $\text{C}_6\text{-C}_{20}$ -aryl,  $\text{C}_7\text{-C}_{20}$ -alkylaryl, or  $\text{C}_7\text{-C}_{20}$ -arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements;

R<sup>2</sup> with R<sup>3</sup>, and R<sup>4</sup> with R<sup>5</sup>, form a 5 or 6 membered unsaturated rings optionally containing heteroatoms belonging to groups 13 -16 of the Periodic Table of the Elements and optionally bearing alkyl substituents, preferably said alkyl substituents are  $\text{C}_1\text{-C}_{10}$ -alkyl radicals;



wherein R is a linear or branched, saturated or unsaturated  $C_1$ - $C_{20}$ -alkyl,  $C_3$ - $C_{20}$ -cycloalkyl,  $C_6$ - $C_{20}$ -aryl,  $C_7$ - $C_{20}$ -alkylaryl, or  $C_7$ - $C_{20}$ -arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements;  $p^1$  ranges from 0 to 5; and  $R^6$ , equal to or different from each other, are hydrogen atoms or a linear or branched, saturated or unsaturated  $C_1$ - $C_{20}$ -alkyl,  $C_3$ - $C_{20}$ -cycloalkyl,  $C_6$ - $C_{20}$ -aryl,  $C_7$ - $C_{20}$ -alkylaryl, or  $C_7$ - $C_{20}$ -arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; with the proviso that at least one  $R^6$  is different from a hydrogen atom;

$T^2$  is a hydrogen atom or a linear or branched, saturated or unsaturated  $C_1$ - $C_{20}$ -alkyl,  $C_3$ - $C_{20}$ -cycloalkyl,  $C_6$ - $C_{20}$ -aryl,  $C_7$ - $C_{20}$ -alkylaryl, or  $C_7$ - $C_{20}$ -arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements;

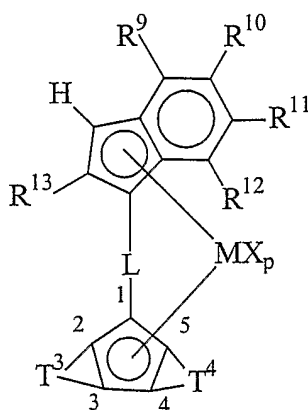
$T^1$  and  $T^2$  can also join to form a saturated or unsaturated, condensed 5 or 6 membered ring optionally containing heteroatoms belonging to groups 13-16 of the Periodic Table of the Elements; said ring can be substituted;

L is a divalent bridging group selected from the group consisting of  $CR^7_2$ ,  $SiR^7_2$ ,  $(CR^7_2)_2$  and  $(SiR^7_2)_2$  radicals, wherein  $R^7$  equal to or different from each other are hydrogen atoms or a linear or branched, saturated or unsaturated  $C_1$ - $C_{20}$ -alkyl,  $C_3$ - $C_{20}$ -cycloalkyl,  $C_6$ - $C_{20}$ -aryl,  $C_7$ - $C_{20}$ -alkylaryl, or  $C_7$ - $C_{20}$ -arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; optionally two  $R^7$  groups can also form an aliphatic ring having 3 to 8 atoms which can bear alkyl substituents, preferably said alkyl substituents are  $C_1$ - $C_{10}$ -alkyl radicals;

M is an atom of a transition metal selected from those belonging to group 3, 4, or to the lanthanide or actinide groups in the Periodic Table of the Elements (new IUPAC version); and

- (B) an alumoxane and/or a compound capable of forming an alkyl metallocene cation.
2. The process according to claim 1 wherein the catalyst system is obtained by further contacting the components (A) and (B) with:
- (C) an organo aluminum compound.

3. The process according to claims 1 or 2 wherein in the metallocene of formula (I) L is  $\text{CR}^7_2$  or  $\text{SiR}^7_2$ ; wherein  $\text{R}^7$  is a hydrogen atom or a methyl or phenyl radical; M is zirconium or hafnium; X is a hydrogen atom, a halogen atom or a  $\text{OR}'\text{O}$  or R group wherein R is a linear or branched, saturated or unsaturated  $\text{C}_1\text{-C}_{20}$ -alkyl,  $\text{C}_3\text{-C}_{20}$ -cycloalkyl,  $\text{C}_6\text{-C}_{20}$ -aryl,  $\text{C}_7\text{-C}_{20}$ -alkylaryl, or  $\text{C}_7\text{-C}_{20}$ -arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements and  $\text{R}'$  is a divalent radical selected from the group consisting of  $\text{C}_1\text{-C}_{20}$ -alkylidene,  $\text{C}_6\text{-C}_{20}$ -arylidene,  $\text{C}_7\text{-C}_{20}$ -alkylarylidene, and  $\text{C}_7\text{-C}_{20}$ -arylalkylidene radicals.
4. The process according to anyone of claims 1-3 wherein the metallocene has formula (II):



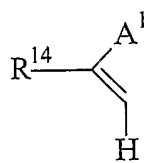
(II)

wherein:

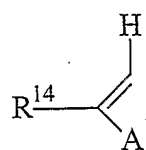
L, M, X and p have the meaning indicated in claims 1 or 2;

$\text{R}^{13}$  is a hydrogen atom or a linear or branched, saturated or unsaturated  $\text{C}_1\text{-C}_{20}$ -alkyl,  $\text{C}_3\text{-C}_{20}$ -cycloalkyl,  $\text{C}_6\text{-C}_{20}$ -aryl,  $\text{C}_7\text{-C}_{20}$ -alkylaryl, or  $\text{C}_7\text{-C}_{20}$ -arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements;  $\text{R}^9$ ,  $\text{R}^{10}$ ,  $\text{R}^{11}$  and  $\text{R}^{12}$  are hydrogen atoms or linear or branched, saturated or unsaturated  $\text{C}_1\text{-C}_{20}$ -alkyl,  $\text{C}_3\text{-C}_{20}$ -cycloalkyl,  $\text{C}_6\text{-C}_{20}$ -aryl,  $\text{C}_7\text{-C}_{20}$ -alkylaryl, or  $\text{C}_7\text{-C}_{20}$ -arylalkyl radicals, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements;  $\text{R}^9$ ,  $\text{R}^{10}$ ,  $\text{R}^{11}$  and  $\text{R}^{12}$  can also form one or more 5 or 6 membered saturated or unsaturated ring optionally containing heteroatoms belonging to groups 13-16 of the Periodic Table of the Elements, said ring can bear alkyl substituents;

$\text{T}^3$  and  $\text{T}^4$  are moieties of formula (IIa) or (IIb):



(IIa)



(IIb)

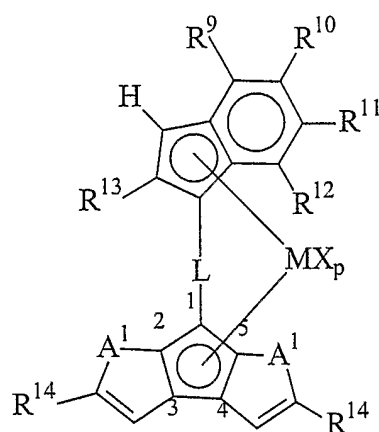
wherein

when  $T^3$  and  $T^4$  are moieties of formula (IIa)  $A^1$  bonds to the cyclopentadienyl group in position 2 and 5;

when  $T^3$  and  $T^4$  are moieties of formula (IIb)  $A^1$  bonds to the cyclopentadienyl group in position 3 and 4;

$A^1$  is a sulphur atom(S), a oxygen atom (O), or a  $NR$ ,  $PR$ , or  $CR^{15}$  group; wherein  $R$  is a linear or branched, saturated or unsaturated  $C_1$ - $C_{20}$ -alkyl,  $C_3$ - $C_{20}$ -cycloalkyl,  $C_6$ - $C_{20}$ -aryl,  $C_7$ - $C_{20}$ -alkylaryl, or  $C_7$ - $C_{20}$ -arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements;  $R^{14}$  is a hydrogen atom or a linear or branched, saturated or unsaturated  $C_1$ - $C_{20}$ -alkyl,  $C_3$ - $C_{20}$ -cycloalkyl,  $C_6$ - $C_{20}$ -aryl,  $C_7$ - $C_{20}$ -alkylaryl, or  $C_7$ - $C_{20}$ -arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements;

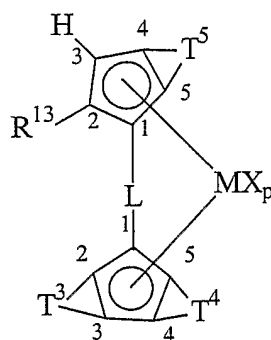
5. The process according to claim 4 wherein  $R^{13}$  is a linear or branched  $C_1$ - $C_{20}$  alkyl radical;  $R^9$  is a  $C_1$ - $C_{20}$  alkyl or  $C_6$ - $C_{20}$  aryl radical;  $R^{10}$ ,  $R^{11}$  and  $R^{12}$  are hydrogen atoms; in the moiety (IIa)  $A^1$  is sulfur and in the moiety (IIb)  $A^1$  is  $NR$  wherein  $R$  is defined as in claim 4;  $R^{14}$  is a  $C_1$ - $C_{20}$  alkyl radical.
6. The process according to claims 4 or 5 wherein the metallocene compound has formula (IIc)



(IIc)

wherein  $R^9$ ,  $R^{10}$ ,  $R^{11}$ ,  $R^{12}$ ,  $R^{13}$ ,  $R^{14}$ ,  $A^1$ ,  $L$ ,  $M$ ,  $X$ , and  $p$  have the meaning described in claims 4 or 5.

7. The process according to anyone of claims 1-3 wherein the metallocene has formula (III):

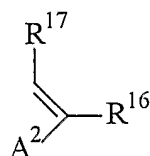


(III)

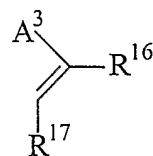
wherein:

$T^3$ ,  $T^4$ ,  $R^{13}$ ,  $M$ ,  $X$ ,  $p$  and  $L$  have the meaning described in anyone of claims 4 or 5;

$T^5$  is a moiety of formula (IIIa) or (IIIb)



(IIIa)



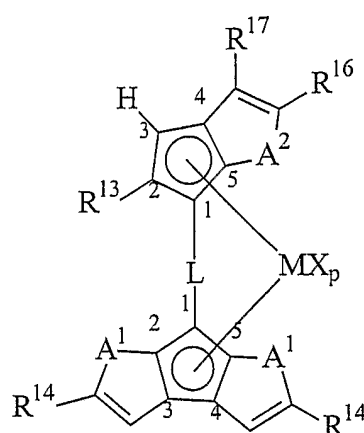
(IIIb)

wherein in the moiety of formula (IIIa)  $A^2$  bonds to the cyclopentadienyl group in position 5; in the moiety of formula (IIIb)  $A^3$  bonds to the cyclopentadienyl group in position 4;



$A^2$  is a sulphur atom (S), an oxygen atom (O), or a  $CR^{15}$  group; wherein  $R^{15}$  has the meaning described in claim 3;  $R^{16}$  is a hydrogen atom or a linear or branched, saturated or unsaturated  $C_1$ - $C_{20}$ -alkyl,  $C_3$ - $C_{20}$ -cycloalkyl,  $C_6$ - $C_{20}$ -aryl,  $C_7$ - $C_{20}$ -alkylaryl, or  $C_7$ - $C_{20}$ -arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements;  $R^{17}$  is a hydrogen atom or a linear or branched, saturated or unsaturated  $C_1$ - $C_{20}$ -alkyl,  $C_3$ - $C_{20}$ -cycloalkyl,  $C_6$ - $C_{20}$ -aryl,  $C_7$ - $C_{20}$ -alkylaryl, or  $C_7$ - $C_{20}$ -arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements;  $R^{17}$  and  $R^{16}$  can also join to form a 5 or 6 membered aliphatic or aromatic ring; said ring can bear alkyl substituents, preferably said alkyl substituents are  $C_1$ - $C_{10}$ -alkyl radicals;  $A^3$  is a NR group or a  $CR^{15}$  group wherein R is a linear or branched, saturated or unsaturated  $C_1$ - $C_{20}$ -alkyl,  $C_3$ - $C_{20}$ -cycloalkyl,  $C_6$ - $C_{20}$ -aryl,  $C_7$ - $C_{20}$ -alkylaryl, or  $C_7$ - $C_{20}$ -arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; and  $R^{15}$  has the meaning described in claims 3 or 4.

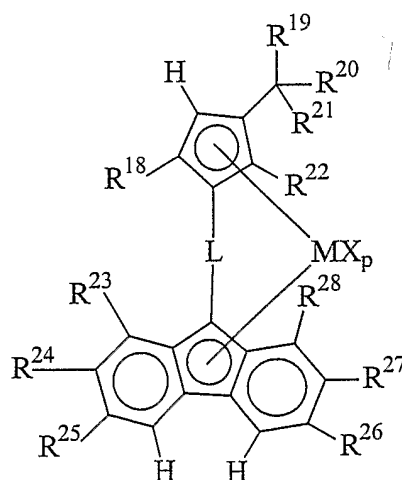
8. The process according to claim 7 wherein  $R^{16}$  is a  $C_1$ - $C_{20}$  alkyl radical;  $R^{17}$  is a  $C_1$ - $C_{20}$  alkyl or a  $C_6$ - $C_{20}$  alkylaryl radical;  $A^2$  is sulfur atom; y  $A^3$  is a NR group, wherein R is a linear or branched, saturated or unsaturated  $C_1$ - $C_{20}$ -alkyl,  $C_3$ - $C_{20}$ -cycloalkyl,  $C_6$ - $C_{20}$ -aryl,  $C_7$ - $C_{20}$ -alkylaryl, or  $C_7$ - $C_{20}$ -arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements.
9. The process according to claims 7 or 8 wherein the metallocene compound has formula (IIIc):



(IIIc)

wherein  $R^{13}$ ,  $R^{14}$ ,  $R^{16}$ ,  $R^{17}$ ,  $A^1$ ,  $A^2$ ,  $L$ ,  $M$ ,  $X$ , and  $p$  have the meaning described in claims 7 or 8.

10. The process according to anyone of claims 1-3 wherein the metallocene has formula (IV):



(IV)

Wherein  $M$ ,  $L$ ,  $X$  and  $p$  have the meaning described in claims 1 or 2;

$R^{18}$ ,  $R^{22}$ ,  $R^{23}$ ,  $R^{24}$ ,  $R^{25}$ ,  $R^{26}$ ,  $R^{27}$  and  $R^{28}$  are hydrogen atoms or a linear or branched, saturated or unsaturated  $C_1$ - $C_{20}$ -alkyl,  $C_3$ - $C_{20}$ -cycloalkyl,  $C_6$ - $C_{20}$ -aryl,  $C_7$ - $C_{20}$ -alkylaryl, or  $C_7$ - $C_{20}$ -arylalkyl radical, optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; or two or more adjacent  $R^{23}$ ,  $R^{24}$ ,  $R^{25}$ ,  $R^{26}$ ,  $R^{27}$ , and  $R^{28}$  can form one or more aliphatic or aromatic  $C_4$ - $C_8$  rings that can bear alkyl substituents, preferably said alkyl substituents are  $C_1$ - $C_{10}$ -alkyl radicals;

$R^{19}$ ,  $R^{20}$  and  $R^{21}$  are hydrogen atoms or a linear or branched, saturated or unsaturated  $C_1$ - $C_{20}$ -alkyl,  $C_3$ - $C_{20}$ -cycloalkyl,  $C_6$ - $C_{20}$ -aryl,  $C_7$ - $C_{20}$ -alkylaryl, or  $C_7$ - $C_{20}$ -arylalkyl radical,

optionally containing heteroatoms belonging to groups 13-17 of the Periodic Table of the Elements; with the proviso that at least one  $R^{19}$ ,  $R^{20}$  and  $R^{21}$  is different from a hydrogen atom.

11. The process according to claim 10 wherein  $R^{22}$ ,  $R^{23}$ ,  $R^{24}$ ,  $R^{25}$ ,  $R^{26}$ ,  $R^{27}$  and  $R^{28}$  are hydrogen atoms;  $R^{18}$  is a hydrogen atom or a  $C_1$ - $C_{20}$  alkyl radical;  $R^{19}$ ,  $R^{20}$ ,  $R^{21}$  are  $C_1$ - $C_{20}$  alkyl radicals.
12. The 1-butene homopolymer having the following characteristics:
  - $(mmmm) > 90 - 2 \times rr$ ;
  - intrinsic viscosity (I.V.)  $> 0.45$ ;
  - 4,1 insertions (regioerrors)  $< 0.19\%$ ; and
  - an extractable content in boiling diethylether  $< 2\%$ ;wherein  
mmmm is the value of the isotactic pentads and rr is the value of the syndiotactic triads.
13. A 1-butene homopolymer having the following characteristics:
  - isotactic pentads  $(mmmm) \geq 90\%$ ;
  - intrinsic viscosity (I.V.)  $> 0.45$ ;
  - 4,1 insertions (regioerrors)  $< 0.19\%$ ; and
  - an extractable content in boiling diethylether  $< 2\%$ .
14. The 1-butene homopolymer according to claims 12 or 13 having a flexural modulus value (ASTM D-790) comprised between 150 and 300 Mpa.

# INTERNATIONAL SEARCH REPORT

Inte 1al Application No

PCT/EP 02/12731

## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 C08F10/08 C08F4/642

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 7 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)

EPO-Internal, WPI Data, PAJ, CHEM ABS Data

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	WO 99 52955 A (RIEGER BERNHARD) 21 October 1999 (1999-10-21)	1-11
A	claims 1,5,11-17; figures; examples ---	12-14
X	DE 199 62 910 A (TARGOR GMBH) 5 July 2001 (2001-07-05) cited in the application page 12, line 38 -page 18, line 22 page 20, line 36 - line 37; claims ---	1-11
X	WO 99 02569 A (UNIV LELAND STANFORD JUNIOR ;WAYMOUTH ROBERT M (US); LECLERC MARGR) 21 January 1999 (1999-01-21) page 3, line 23 -page 7, line 2 page 10, line 26 -page 11, line 3; claims; examples --- -/--	1-11

☒ Further documents are listed in the continuation of box C.

☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

11 March 2003

Date of mailing of the international search report

20/03/2003

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# INTERNATIONAL SEARCH REPORT

Inter al Application No  
PCT/EP 02/12731

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
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X	US 6 180 732 B1 (EWEN JOHN A) 30 January 2001 (2001-01-30) column 13, line 28 - line 51 column 14, line 37 - line 42; claims ----	1-11
X	EP 0 786 466 A (TOSOH CORP) 30 July 1997 (1997-07-30) page 12, line 46; claims ----	1-11
X	WO 99 45043 A (MONTELL TECHNOLOGY COMPANY BV) 10 September 1999 (1999-09-10) cited in the application the whole document ----	12-14
X	JP 60 262804 A (MITSUI SEKIYU KAGAKU KOGYO KK) 26 December 1985 (1985-12-26) abstract ----	12-14
X	& PATENT ABSTRACTS OF JAPAN , 20 May 1986 (1986-05-20) & JP 60 262804 A (MITSUI PETROCHEMICAL IND), 26 December 1985 (1985-12-26) abstract ----	12-14
A	WO 01 47939 A (RESONI LUIGI ;GUIDOTTI SIMONA (IT); BASELL TECHNOLOGY COMPANY B V) 5 July 2001 (2001-07-05) cited in the application claims -----	1-11

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Inte 1al Application No

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