P/00/001 28/5/91
Section 29

AUSTRALIA
Patents Act 1990

648172

PATENT REQUEST: STANDARD PATENT/PATENT OF ADDITION

I/We, being the person(s) identified below as the Applicant, request the grant of a patent to the person identified below as the Nominated Person, for an invention described in the accompanying standard complete specification.

Full application details follow.

[71] Applicant: HOECHST AKTIENGESELLSCHAFT

Address: D-6230 Frankfurt/Main 80, Federal Republic of Germany

[70] Nominated Person: HOECHST AKTIENGESELLSCHAFT

Address: D-6230 Frankfurt/Main 80, Federal Republic of Germany

[54] Invention Title: PROCESS FOR THE PREPARATION OF SYNDIOTACTIC POLYOLEFINS HAVING A BROAD MOLECULAR WEIGHT DISTRIBUTION

[72] Name(s) of actual inventor(s): ANDREAS WINTER, VOLKER DOLLE and WALTER SPALECK

[74] Address for service in Australia: c/o WATERMARK PATENT & TRADEMARK ATTORNEYS, of The Atrium, 290 Burwood Road, Hawthorn, Victoria 3122, Australia Attorney Code: WM

BASIC CONVENTION APPLICATION(S) DETAILS

[31] Application Number	[33] Country	Country Code	[32] Date of Application
P41 17 260.4	Germany	DE	27th May 1991

Drawing number recommended to accompany the abstract .....

By my/our Patent Attorneys,
WATERMARK PATENT & TRADEMARK ATTORNEYS

.....
D. B. Mischlewski

25th May 1992
(Date)

Registered Patent Attorney

F034204 26/05/92

P/00/0088 12/11/91
Section 29 (1)
Regulation 3.1 (2)

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NOTICE OF ENTITLEMENT

We, **HOECHST AKTIENGESELLSCHAFT** of, D-6230 Frankfurt/Main 80, Federal Republic of Germany being the applicant in respect of Application No. **17134/92** state the following:-

The Person nominated for the grant of the patent has entitlement from the actual inventors by virtue of an employment contract between the inventors and the nominated person.

The person nominated for the grant of the patent is the applicant of the basic application listed on the patent request form.

The basic application listed on the request form is the first application made in a Convention country in respect of the invention.

HOECHST AKTIENGESELLSCHAFT

By our Patent Attorneys,
WATERMARK PATENT & TRADEMARK ATTORNEYS

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Darryl B. Mischlewski

Registered Patent Attorney

31 January 1994

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AU9217134

(12) PATENT ABRIDGMENT (11) Document No. AU-B-17134/92
(19) AUSTRALIAN PATENT OFFICE (10) Acceptance No. 648172

(54) Title
PROCESS FOR THE PREPARATION OF SYNDIOTACTIC POLYOLEFINS HAVING A BROAD MOLECULAR WEIGHT DISTRIBUTION

International Patent Classification(s)
(51)[5] **C08F 004/64** **C08F 004/76** **C08F 004/642**

(21) Application No. : **17134/92** (22) Application Date : **26.05.92**

(30) Priority Data

(31) Number	(32) Date	(33) Country
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(71) Applicant(s)
HOECHST AKTIENGESELLSCHAFT

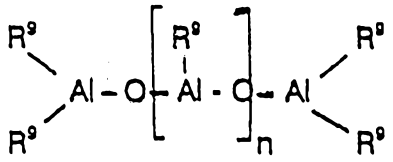
(72) Inventor(s)
ANDREAS WINTER; VOLKER DOLLE; WALTER SPALECK

(74) Attorney or Agent
WATERMARK PATENT & TRADEMARK ATTORNEYS , Locked Bag 5, HAWTHORN VIC 3122

(56) Prior Art Documents
AU 17133/92 C08F 4/00

(57) Claim

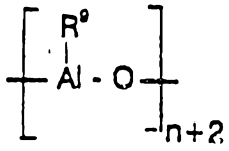
1. A process for the preparation of a syndiotactic polyolefin which has a molecular weight distribution M_w/M_n of ≥ 3.0 and which may be monomodal, bimodal or multimodal, by polymerization or copolymerization of an olefin of the formula $R^aCH=CHR^b$ in which R^a and R^b are identical or different and are a hydrogen atom or a alkyl radical having 1 to 14 carbon atoms, or R^a and R^b, together with the atoms connecting them, can form a ring, at a temperature of from -60 to 200°C, at a pressure of from 0.5 to 100 bar, in solution, in suspension or in the gas phase, in the presence of a catalyst comprising a transition-metal component (metallocene) and an aluminoxane of the formula II



(II)

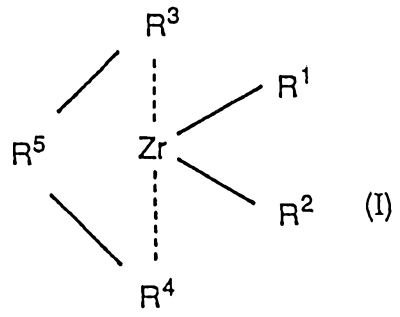
.../2

for the linear type and/or of the formula III



(III)

for the cyclic type, where, in the formulae II and III, the radicals R^9 may be identical or different and are a C_1-C_6-alkyl group, a C_1-C_6-fluoroalkyl group, a C_6-C_{18}-aryl group, a C_6-C_{18}-fluoroaryl group or hydrogen, and n is an integer from 0 to 50, or, instead of the aluminoxane, comprises a mixture of an aluminoxane of the formula II and/or of the formula III with a compound AlR^9_3, which comprises using, as the transition-metal component, at least 2 metallocenes of the formula I



(I)

which are stereorigid and whose moiety formed by Zr and the substituents R1-R2 has C_s symmetry or slightly distorted C_s symmetry as hereinbefore defined, and in which R1 and R2 are identical or different and are a hydrogen atom, a halogen atom, a C_1-C_{10}-alkyl group, a C_1-C_{10}-alkoxy group, a C_6-C_{10}-aryl group, a C_2-C_{10}-aryloxy group, a C_2-C_{10}-alkenyl group, a C_7-C_{40}-arylalkyl group, a C_7-C_{40}-alkylaryl group or a C_8-C_{40}-arylalkenyl group,

R3 and R4 are different and are monocyclic or polycyclic hydrocarbon radicals which can form a sandwich structure together with the central atom Zr,

R^5 is a single- or multimembered bridge which links the radicals R^3 and R^4 and is

$$-M^1(R^6)(R^7)-, \quad -M^1(R^6)(R^7)-M^1(R^6)(R^7)-, \quad -M^1(R^6)-C^8{}_2(R^6)-, \quad -C(R^6)(R^7)-, \quad -O-M^1(R^6)(R^7)-, \quad -C(R^6)(R^7)-C(R^6)(R^7)-,$$

$=BR^6$, $=AlR^6$, -GE-, -Sn, -O-, -S-, $=SO$, $=SO_2$, $=NR^6$, $=CO$, $=PR^6$ or $P(O)R^6$, where R^6, R^7 and R^8 are identical or different and are a hydrogen atom, a halogen atom, a C_1-C_{10}-alkyl group, a C_1-C_{10}-fluoroalkyl group, a C_6-C_{10}-fluoroaryl group, a C_6-C_{10}-aryl group, a C_1-C_{10}-alkoxy group, a C_2-C_{10}-alkenyl group, a C_7-C_{40}-arylalkyl group, a C_8-C_{40}-arylalkenyl group or a C_7-C_{40}-alkylaryl group, or R^6 and R^7 or R^6 and R^8, together with the atoms connecting them, in each case form a ring, and M^1 is silicon, germanium or tin.

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Regulation 3.2(2)

AUSTRALIA

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48172

ORIGINAL
COMPLETE SPECIFICATION
STANDARD PATENT

Application Number:

Lodged:

Invention Title: PROCESS FOR THE PREPARATION OF SYNDIOTACTIC POLYOLEFINS HAVING A BROAD MOLECULAR WEIGHT DISTRIBUTION

The following statement is a full description of this invention, including the best method of performing it known to :- us

HOECHST AKTIENGESELLSCHAFT - HOE 91/F 159 Dr. LO/sch

Description

Process for the preparation of syndiotactic polyolefins having a broad molecular weight distribution

It is known that metallocene catalysts in combination with aluminoxanes as cocatalysts are capable of polymerizing olefins to give polyolefins having a narrow molecular weight distribution, M_w/M_n of 2-3 (J. Polym. Sci., Pol. Chem. Ed. 23 (1985) 2117, EP-A 302 424).

Polyolefins of this type with a narrow distribution are suitable, for example, for applications in precision injection molding, injection molding in general and for the production of fibers. For numerous applications, such as, for example, thermoforming, extrusion, blow molding and for the production of polyolefin foams and films, broader or bimodal molecular weight distributions are required.

For polyethylene, it has been proposed to achieve such products by using two or more metallocene catalysts in the polymerization (EP-A 128 045). The systems described are achiral catalysts and would give atactic polypropylene on polymermization of propene. However, atactic polypropylene is unsuitable as a structural material.

The preparation of stereoblock polypropylene where M_w/M_n is 13-15 is disclosed in DE-A 3 640 924. These catalyst systems are likewise unsuitable for the formation of polyolefins of high tacticity. Furthermore, the molecular weights which can be achieved at industrially relevant polymerization temperatures are too low.

EP-A 310 734 proposes polymerization systems comprising a mixture of a hafnocene and a zirconocene, both of which are chiral and stereorigid, for the preparation of highly

isotactic polypropylene. The products obtained have broad to bimodal distributions where M_w/M_n is from 3.7 to 10.3

If only a hafnocene catalyst is used, isotactic polypropylene with a broad distribution is obtained at a certain polymerization temperature, according to EP-A 355 439.

Syndiotactic polypropylene having a broad or bimodal distribution (M_w/M_n > 6.4) is prepared in EP-A 387 691 using a hafnocene catalyst.

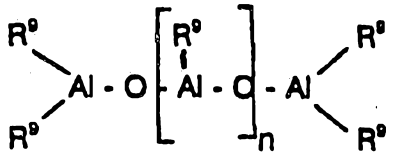
These processes have the disadvantages of hafnium catalyst costs which are too high for industrial applications, together with a low polymerization activity, which additionally makes it necessary to carry out thorough, high-cost purification of the prepared polymer to remove catalyst residues.

The object was thus to find a catalyst system and a process by means of which syndiotactic polyolefins having a broad to bimodal distribution can be prepared and which are suitable for industrial applications.

The object is achieved by using a catalyst system comprising at least two specific zirconocenes, which are stereorigid and prochiral, but are not necessary chiral, and which have C_s symmetry or only slightly distorted C_s symmetry, and an aluminum compound as cocatalyst.

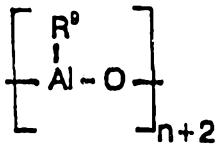
The Invention thus relates to a process for the preparation of a syndiotactic polyolefin which has a molecular weight distribution M_w/M_n of ≥ 3.0 and which may be monomodal, bimodal or multimodal, by polymerization or copolymerization of an olefin of the formula $R^aCH=CHR^b$ in which R^a and R^b are identical or different and are hydrogen atom or alkyl radical having 1 to 14 carbon atoms, or R^a and R^b, together with the atoms connecting them, can form a ring, at a temperature of from -60 to 200°C, at a

pressure of from 0.5 to 100 bar, in solution, in suspension or in the gas phase, in the presence of a catalyst comprising a transition-metal component (metallocene) and an aluminoxane of the formula II



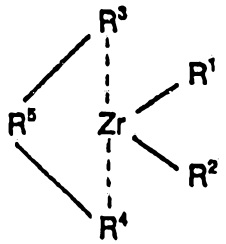
(II)

for the linear type and/or of the formula III



(III)

for the cyclic type, where, in the formulae II and III, the radicals R^9 may be identical or different and are a C_1-C_6-alkyl group, a C_1-C_6-fluoroalkyl group, a C_6-C_{18}-aryl group, a C_6-C_{18}-fluoroaryl group or hydrogen, and n is an integer from 0 to 50, or, instead of the aluminoxane, comprises a mixture of an aluminoxane of the formula II and/or of the formula III with a compound AlR^9_3, which comprises using, as the transition-metal component, at least 2 metallocenes of the formula I

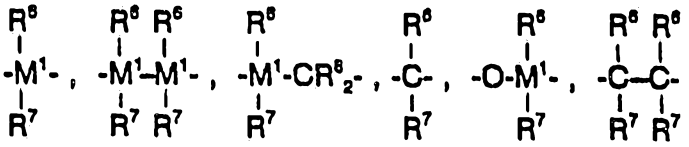


(I)

which are stereorigid and whose moiety formed by Zr and

the substituents R^1-R^4 has C_s symmetry or slightly distorted C_s symmetry, and in which R^1 and R^2 are identical or different and are a hydrogen atom, a halogen atom, a C_1-C_{10}-alkyl group, a C_1-C_{10}-alkoxy group, a C_6-C_{10}-aryl group, a C_6-C_{10}-aryloxy group, a C_2-C_{10}-alkenyl group, a C_7-C_{40}-arylalkyl group, a C_7-C_{40}-alkylaryl group or a C_8-C_{40}-arylalkenyl group,

R^3 and R^4 are different and are monocyclic or polycyclic hydrocarbon radicals which can form a sandwich structure together with the central atom Zr,

R^5 is 

=BR^6, =AlR^6, -Ge-, -Sn, -O-, -S-, =SO, =SO_2, =NR^6, =CO, =PR^6 or =P(O)R^6, where R^6, R^7 and R^8 are identical or different and are a hydrogen atom, a halogen atom, a C_1-C_{10}-alkyl group, a C_1-C_{10}-fluoroalkyl group, a C_6-C_{10}-fluoroaryl group, a C_6-C_{10}-aryl group, a C_1-C_{10}-alkoxy group, a C_2-C_{10}-alkenyl group, a C_7-C_{40}-arylalkyl group, a C_8-C_{40}-arylalkenyl group or a C_7-C_{40}-alkylaryl group, or R^6 and R^7 or R^6 and R^8, together with the atoms connecting them, in each case form a ring, and M^1 is silicon, germanium or tin.

Alkyl here is straight-chain or branched alkyl and halogen is preferably fluorine or chlorine, in particular chlorine.

For the purposes of the present invention, the term C_s symmetry means that the metallocenes I have a mirror plane in the Zr, R^1-R^4 moiety perpendicular to the plane passing through Zr, R^1 and R^2. The bisecting line of the angle R^1-Zr-R^2 extends in this mirror plane.

In the case of slightly distorted C_s symmetry, R^1 may be different from R^2 or the radicals R^3 and/or R^4 are substituted (such as, for example, methylcyclopentadienyl). Preferred metallocenes are those whose C_s symmetry is not distorted.

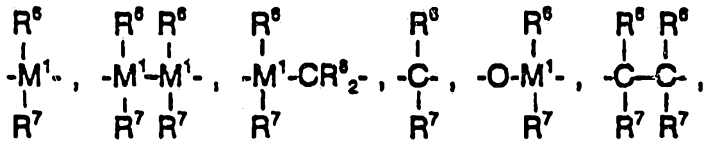
It should be noted here that the term C_s symmetry and its scope of meaning are determined by a formal (idealized) consideration of the metallocene molecule I. This means that shifts in said moiety, for example caused by the bridge R^5, which would arise in a complete structural determination (X-ray structural analysis) and could not be regarded as C_s-symmetrical if considered strictly, remain unconsidered for the purposes of the present invention.

The following also applies to the formula I:

R^1 and R^2 are identical or different and are a hydrogen atom, a C_1-C_{10}-, preferably C_1-C_3-alkyl group, a C_1-C_{10}-, preferably C_1-C_3-alkoxy group, a C_6-C_{10}-, preferably C_6-C_8-aryl group, a C_6-C_{10}-, preferably C_6-C_8-aryloxy group, a C_2-C_{10}-, preferably C_2-C_4-alkenyl group, a C_7-C_{40}-, preferably C_7-C_{10}-arylalkyl group, a C_7-C_{40}-, preferably C_7-C_{12}-alkylaryl group, a C_8-C_{40}-, preferably C_8-C_{12}-arylalkenyl group, or a halogen atom, preferably chlorine, R^3 and R^4 are different and are monocyclic or polycyclic hydrocarbon radicals which can form a sandwich structure together with the central atom Zr.

R^3 and R^4 are preferably fluorenyl and cyclopentadienyl, it being possible for the parent structures to carry additional substituents as defined for R^6.

R^5 is a single- or multimembered bridge which links the radicals R^3 and R^4 and is



$=BR^6$, $=AlR^6$, -Ge-, -Sn, -O-, -S-, =SO, $=SO_2$, $=NR^6$, =CO, $=PR^6$ or $=P(O)R^6$, where R^6, R^7 and R^8 are identical or different and are a hydrogen atom, a halogen atom, preferably chlorine, a C_1-C_{10}-, preferably C_1-C_3-alkyl group, in particular methyl group, a C_1-C_{10}-fluoroalkyl group, preferably CF_3 group, a C_6-C_{10}-fluoroaryl group, preferably pentafluorophenyl group, a C_6-C_{10}-, preferably C_6-C_8-aryl group, a C_1-C_{10}-, preferably C_1-C_4-alkoxy group, in particular methoxy group, a C_2-C_{10}-, preferably C_2-C_4-alkenyl group, a C_7-C_{40}-, preferably C_7-C_{10}-arylalkyl group, a C_8-C_{40}-, preferably C_8-C_{12}-arylalkenyl group, or a C_7-C_{40}-, preferably C_7-C_{12}-alkylaryl group, or R^6 and R^7 or R^6 and R^8, together with the atoms connecting them, in each case form a ring.

M^1 is silicon, germanium or tin, preferably silicon or germanium.

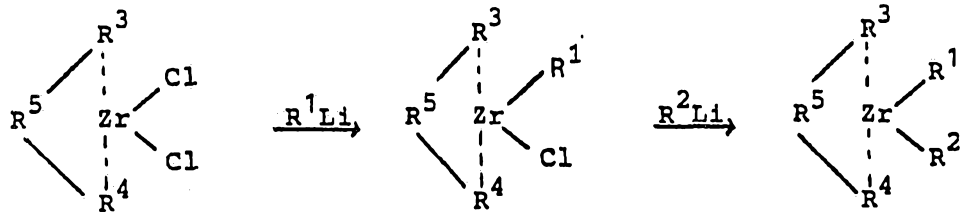
R^5 is preferably $=CR^6R^7$, $=SiR^6R^7$, $=GeR^6R^7$, -O-, -S-, =SO, $=PR^6$ or $=P(O)R^6$. The above-described metallocenes can be prepared by the general reaction scheme below:

H_2R^3 + butylLi → HR^3Li

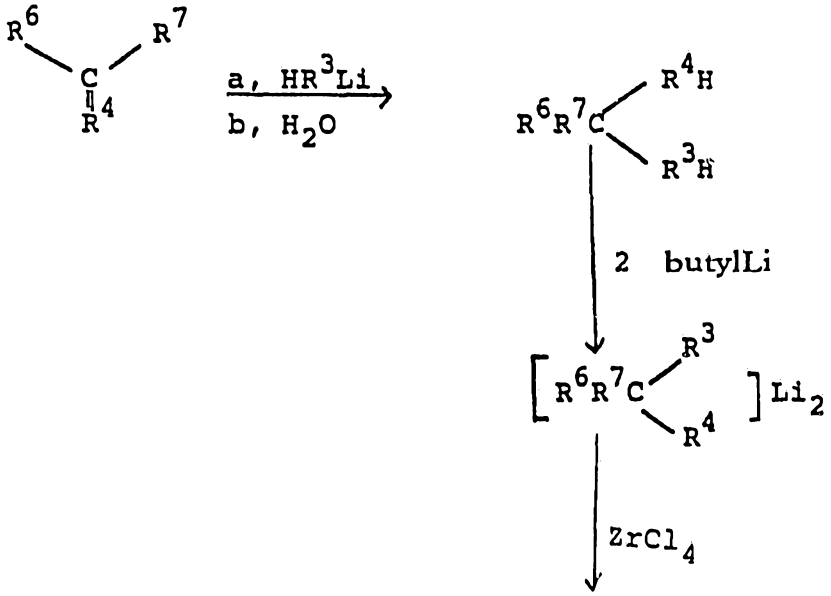
$\xrightarrow{X\text{-}R^5\text{-}X}$ $HR^3\text{-}R^5\text{-}R^4H$ $\xrightarrow{2\text{-ButylLi}}$

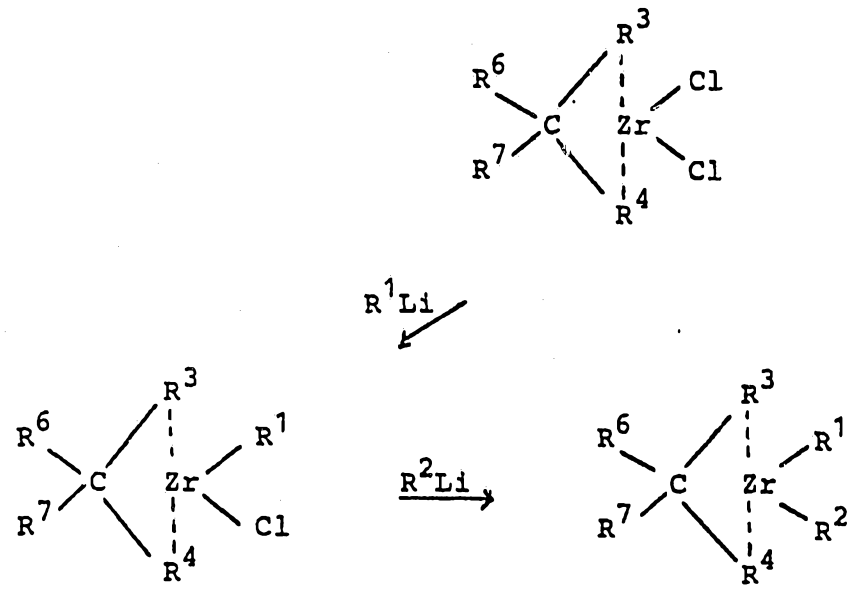
H_2R^4 + butylLi → HR^4Li

$LiR^3\text{-}R^5\text{-}R^4Li$ $\xrightarrow{ZrCl_4}$



(X = Cl, Br, I, O-tosyl)
or
H_2R^3 + butylLi → HR^3Li





(cf. Journal of Organomet. Chem. (1985) 63-67 and EP-A 320 762).

The choice of the metallocenes for the polymerization of olefins to give polyolefins having a broad or multimodal distribution can take place by means of a test polymerization for each metallocene (cf. working examples). In this test, the olefin is polymerized to the polyolefin and the mean molecular weight M_w thereof and the molecular weight distribution M_w/M_n thereof are determined by means of gel permeation chromatography. Depending on the desired molecular weight distribution, the metallocenes are then combined. Taking into account the polymerization activities, it is then possible, for example by means of computer simulation of the combined gel permeation curves, to directly produce any desired molecular weight distribution via the type of metallocenes and via the ratio of the amounts of the metallocenes to one another.

The number of metallocenes I to be used according to the invention is preferably 2 or 3, in particular 2. However, it is also possible to use a greater number (such as, for example, 4 or 5).

By including the polymerization activities and molecular weights at various polymerization temperatures, in the presence of hydrogen as molecular weight regulator or in the presence of comonomers, the computer simulation model can be further refined and the applicability of the process according to the invention further improved.

Preferred metallocenes are (arylalkylidene)(9-fluorenyl)(cyclopentadienyl)zirconium dichloride, (diarylmethylene)(9-fluorenyl)(cylcopentadienyl)zirconium dichloride and (dialkylmethylene)(9-fluorenyl)-(cyclopentadienyl)zirconium dichloride.

Particular preference is given to (methyl(phenyl)methylene)(9-fluorenyl)(cyclopentadienyl)-zirconium dichloride, (diphenylmethylene)(9-fluorenyl)-(cyclopentadienyl)zirconium dichloride and (dimethylmethylene)(9-fluorenyl)(cyclopentadienyl)zirconium dichloride.

The cocatalyst used is an aluminoxane of the formula II and/or III, where n is an integer from 0 to 50, preferably 10 to 35.

The radicals R^9 are preferably identical and are methyl, isobutyl, phenyl or benzyl, particularly preferably methyl.

If the radicals R^9 are different, they are preferably methyl and hydrogen or alternatively methyl and isobutyl, hydrogen or isobutyl preferably being present to the extent of 0.01-40% (number of radicals R^9).

The aluminoxane can be replaced as cocatalyst by a mixture comprising aluminoxane and AlR^9_3. The aluminoxane can be prepared in various ways by known processes. One of the methods is, for example, to react an aluminum hydrocarbon compound and/or a hydridoaluminum hydrocarbon compound with water (gaseous, solid, liquid or bound - for example as water of crystallization) in an inert solvent (such as, for example, toluene). To prepare an aluminoxane containing different alkyl groups R^9, two different trialkylaluminum compounds (AlR_3 + AlR'_3), corresponding to the desired composition, are reacted with water (cf. S. Pasynkiewicz, Polyhedron 9 (1990) 429 and EP-A 302 424).

The precise structure of the aluminoxanes II and III is unknown.

Irrespective of the preparation method, all aluminoxane solutions have in common a varying content of unreacted aluminum starting compound, which is in free form or as an adduct.

It is possible, before use in the polymerization reaction, to preactivate the metallocenes, in each case separately or together as a mixture, by means of an aluminoxane of the formula (II) and/or (III). This significantly increases the polymerization activity and improves the particle morphology.

The preactivation of the metallocenes is carried out in solution. The metallocenes are preferably dissolved, as solids, in a solution of the aluminoxane in an inert hydrocarbon. Suitable inert hydrocarbons are aliphatic or aromatic hydrocarbons. Toluene or a C_6-C_{10}-hydrocarbon is preferably used.

The concentration of the aluminoxane in the solution is in the range from about 1% by weight to the saturation limit, preferably from 5 to 30% by weight, in each case

based on the total solution. The metallocenes can be employed in the same concentration, but are preferably employed in an amount of from 10^{-4}-1 mole per mole of aluminoxane. The preactivation time is from 5 minutes to 60 hours, preferably from 5 to 60 minutes. The temperature used is from -78°C to 100°C, preferably from 0 to 70°C.

The metallocenes may also be prepolymerized or applied to a support. Prepolymerization is preferably carried out using the (or one of the) olefin(s) employed in the polymerization.

Examples of suitable supports are silica gels, aluminum oxides, solid aluminoxane or other inorganic support materials. Another suitable support material is a polyolefin powder in finely divided form.

A further possible embodiment of the process according to the invention comprises using a salt-like compound of the formula $R_xNH_{4-x}BR'_4$ or of the formula $R_3PHBR'_4$ as cocatalyst in place of or in addition to an aluminoxane. In these formulae, x = 1, 2 or 3, R = alkyl or aryl, identical or different, and R' = aryl, which may also be fluorinated or partially fluorinated. In this case, the catalyst comprises the product of the reaction of the metallocenes with one of said compounds (cf. EP-A 277 004).

In order to remove the catalyst poisons present in the olefin, purification by means of an alkylaluminum compound, for example $AlMe_3$ or $AlEt_3$, is advantageous. This purification can be carried out either in the polymerization system itself, or the olefin is brought into contact with the Al compound before addition to the polymerization system and is subsequently removed again.

The polymerization or copolymerization is carried out in a known manner in solution, in suspension or in the gas phase, continuously or batchwise, in one or more steps,

at a temperature of from -60 to 200°C, preferably from 20 to 80°C. Olefins of the formula R^a-CH=CH-R^b are polymerized or copolymerized. In this formula R^a and R^b are identical or different and are hydrogen atoms or alkyl radicals having 1 to 14 carbon atoms. However, R^a and R^b may also form a ring with the carbon atoms connecting them. Examples of such olefins are ethylene, propylene, 1-butene, 1-hexene, 4-methyl-1-pentene, 1-octene, norbornene and norbornadiene. In particular, propylene and ethylene are polymerized.

If necessary, hydrogen is added as molecular weight regulator.

The overall pressure in the polymerization system is from 0.5 to 100 bar. The polymerization is preferably carried out in the industrially particularly interesting pressure range of from 5 to 64 bar.

The metallocenes are preferably used in a concentration, based on the transition metal, of from 10^{-3} to 10^{-8} mol, more preferably from 10^{-4} to 10^{-7} mol, of transition metal per dm^3 of solvent or per dm^3 of reactor volume. The aluminoxane or the aluminoxane/AlR^9_3 mixture is preferably used in a concentration of from 10^{-5} to 10^{-1} mol, more preferably from 10^{-4} to 10^{-2} mol, per dm^3 of solvent or per dm^3 of reactor volume. In principle, however, higher concentrations are also possible.

If the polymerization is carried out as a suspension or solution polymerization, an inert solvent which is customary for the Ziegler low-pressure process is used. For example, the polymerization is carried out in an aliphatic or cycloaliphatic hydrocarbon; the examples of these which may be mentioned are butane, pentane, hexane, heptane, decane, isooctane, cyclohexane and methylcyclohexane. It is also possible to use a gasoline or hydrogenated diesel oil fraction. Toluene can also be used. The polymerization is preferably carried out in the

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liquid monomer.

If inert solvents are used, the monomers are metered in in gaseous or liquid form.

The polymerization can take as long as desired, since the catalyst system used according to the invention only exhibits a slight decrease in the polymerization activity with time.

The process according to the invention is distinguished by the fact that the metallocenes described give polymers having a broad, bimodal or multimodal molecular weight distribution, high molecular weight, high syndiotacticity and good particle morphology in the industrially interesting temperature range between 20 and 80°C with high polymerization activity.

The polymers according to the invention are particularly suitable for the production of films, in particular transparent films, thermoforming applications, polyolefin foams, extrusion applications and for the production of transparent hollow articles and for blow molding in general.

The examples below are intended to illustrate the invention in greater detail.

The following abbreviations are used:

VN = viscosity number in cm^3/g

M_w = weight average molecular weight in g/mol
M_n = number average molecular weight in g/mol
M_w/M_n = molecular weight dispersity
(=molecular weight distribution)
} determined by gel permeation chromatography

SI = syndiotactic index (SIrr + 1/2 mr) determined by ^{13}C-NMR spectroscopy

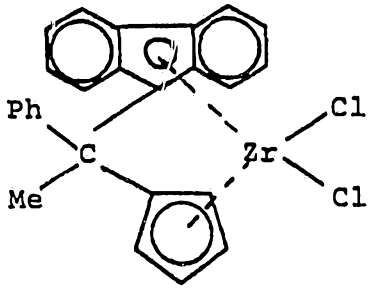
n_{syn} = syndiotactic block length

MFI (230/5) = melt flow index, measured in accordance with DIN 53735; in g/10 min.

A. Preparation of suitable metallocenes

All the working operations given below in the synthesis of metallocenes were carried out under a protective gas using absolute solvents.

Example 1
(Phenyl(methyl)methylene)(9-fluorenyl)(cyclopentadienyl)-zirconium dichloride



A solution of 67.8 mmol of fluorenyllithium in 50 cm^3 of THF was added at room temperature to a solution of 11.4 g (67.8 mmol) of 6-methyl-6-phenylfulvene in 40 cm^3 of THF. The mixture was stirred at room temperature for 2 hours, and 60 cm^3 of water were added. The substance which precipitated was filtered off with suction, washed with diethyl ether and dried in an oil-pump vacuum. 19.1 g (84.2%) of 2,2-cyclopentadienyl(9-fluorenyl)ethyl-benzene (correct elemental analyses; ^{1}H-NMR spectrum) were obtained.

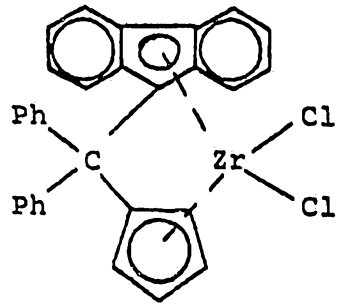
10.0 g (29.9 mmol) of the compound were dissolved in 60 cm^3 of THF, and 26 cm^3 (65 mmol) of a 2.5 molar hexane solution of n-butyllithium were added at 0°C. After the mixture had been stirred for 15 minutes, the solvent was stripped off in vacuo. The dark red residue which remained was washed several times with hexane and dried

in an oil-vacuum. 15.6 g of the red dilithio salt were obtained as the THF adduct; it contained about 30% of THF.

14.9 mmol of the dilithio salt were added at -78°C to a suspension of 3.48 g (14.9 mmol) of $ZrCl_4$ in 70 cm^3 of CH_2Cl_2. After the batch had been slowly warmed to room temperature, it was stirred at room temperature for a further hour and filtered through a G4 frit; the residue was washed several times with CH_2Cl_2. The red filtrate was evaporated to dryness and the orange-red residue was recrystallized from CH_2Cl_2. 1.8 g (25%) of methylphenylmethylene(cyclopentadienyl)(9-fluorenyl)zirconium dichloride were obtained as a pink crystal powder. ^{1}H-NMR spectrum (100 MHz, $CDCl_3$): 7.1 - 8.25 (m, Flu-H, Ph-H), 6.90 (m, Ph-H), 6.10-6.50 (m, Ph-H, Cp-H), 5.90, 5.75 (2 x m, Cp-H), 2.55 (s, CH_3).

Example 2

Diphenylmethylene(9-fluorenyl)(cyclopentadienyl)zirconium dichloride



12.3 cm^3 (30.7 mmol) of a 2.5 molar hexane solution of n-butyllithium were added slowly at room temperature to a solution of 5.10 g (30.7 mmol) of fluorene in 60 cm^3 of THF. After 40 minutes, 7.07 g (30.7 mmol) of diphenylfulvene were added to the orange solution, and the mixture was stirred overnight. 60 cm^3 of water were

added to the dark red solution, the solution becoming a yellow color, and the solution was extracted with ether. The ether phase was dried over $MgSO_4$, evaporated and left to crystallize at -35°C. 5.1 g (42%) of 1,1-cyclopentadienyl(9-fluorenyl)diphenylmethane were obtained as a beige powder.

6.4 cm^3 (10 mmol) of a 1.6 molar solution of butyllithium in hexane were added at 0°C to 2.0 g (5.0 mmol) of the compound dissolved in 20 cm^3 of THF. The mixture was stirred at room temperature for 15 minutes, the solvent was stripped off, and the red residue was dried in an oil-pump vacuum and washed several times with hexane. After drying in an oil-pump vacuum, the red powder was added at -78°C to a suspension of 1.16 g (6.00 mmol) of $ZrCl_4$. The batch was slowly warmed and then stirred at room temperature for 2 hours. The pink suspension was filtered through a G3 frit. The pink residue was washed with 20 cm^3 of CH_2Cl_2, dried in an oil-pump vacuum and extracted with 120 cm^3 of toluene. The solvent was stripped off and the residue was dried in an oil-pump vacuum, giving 0.55 g of the zirconium complex in the form of a pink crystal powder.

The orange-red filtrate from the reaction batch was evaporated and left to crystallize at -35°C. A further 0.45 g of the complex crystallized from CH_2Cl_2. Total yield 1.0 g (36%). Correct elemental analyses. The mass spectrum showed M^+ = 556. ^{1}H-NMR spectrum (100 MHz, $CDCl_3$); 6.90-8.25 (m, 16, Flu-H, Ph-H), 6.40 (m, 2, Ph-H), 6.37 (t, 2, Cp-H), 5.80 (t, 2, Cp-H).

The metallocene dimethylmethylene(fluorenyl)(cyclopentadienyl)zirconium dichloride was prepared as described in the reference J. Am. Chem. Soc. 110 (1988) 6255.

In order to specifically prepare the desired molecular weight distribution M_w/M_n (width of the molecular weight distribution, monomodal, bimodal or multimodal), the

employed to this end in the combination must be known. To this end, at least one test polymerization is carried out for each of the possible metallocenes.

The examples below demonstrate, with reference to three suitable metallocenes, the procedure and the possible metallocene combinations for the preparation of the broad or multimodal molecular weight distribution according to the invention.

Test polymerizations

Example 3

A dry 16 dm^3 reactor was flushed with nitrogen and filled with 10 dm^3 of liquid propylene. 30 cm^3 of a toluene solution of methylaluminoxane (corresponding to 40 mmol of Al, mean degree of oligomerization of the methylaluminoxane n = 20) were then added, and the batch was stirred at 30°C for 15 minutes. In parallel, 11.9 mg (0.023 mmol) of diphenylmethylene(9-fluorenyl)(cyclopentadienyl)zirconium dichloride were dissolved in 15 cm^3 of a toluene solution of methylaluminoxane (20 mmol of Al). After 15 minutes, the solution was introduced into the reactor, and the polymerization temperature was increased to 60°C. After a polymerization time of 1 hour, the polymerization was terminated. 0.95 kg of polypropylene were obtained, corresponding to a metallocene activity of 79.8 kg of polypropylene/g of metallocene × h.

VN = 459 cm^3/g; M_w = 547,000, M_n = 188,000, M_w/N_n = 2.9, SI = 96.5%; n_{syn} = 38.4; MFI 230/5 = < 0.1 g/10 min.

Example 4

The procedure was analogous to Example 3, but 13.5 mg (0.027 mmol) of phenyl(methyl)methylene(9-fluorenyl)-(cyclopentadienyl)zirconium dichloride were employed. 0.94 kg of polypropylene were obtained, corresponding to a metallocene activity of 69.5 kg of polypropylene/g of metallocene × h.

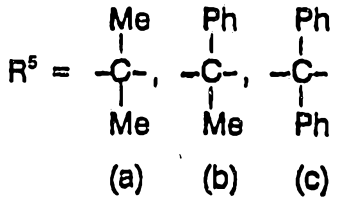
VN = 364 cm^3/g; M_w = 490,000 g/mol; M_w/M_n = 2.6;

SI = 97.0%; n_{syn} = 40.2; MFI (230/5) = 0.25 g/10 min.

Example 5

The procedure was analogous to Example 3, but 13.9 mg (0.032 mmol) of dimethylmethylene(9-fluorenyl)(cyclopentadienyl)zirconium dichloride were employed. After a polymerization time of 2.5 hours, 2.56 kg of polypropylene were obtained, corresponding to a metallocene activity of 73.7 kg of polypropylene/g of metallocene × h. VN = 125 cm^3/g; M_w = 95250 g/mol; M_w/M_n = 2.1; SI = 94.6%; MFI (230/5) = 55 g/10 min.

Examples 3 to 5 show that, for example by varying the radical R^5 in formula I



polymers of low (a), medium (b) and high (c) molecular weight can be prepared. Other modifications of the metallocene ligand sphere of the compounds of the formula I give comparable differences. The combinations according to the invention of such metallocenes give products having the broad or multimodal molecular weight distributions according to the invention and are described in greater detail in the examples below.

Preparation of polymers having a broad and/or bimodal molecular weight distribution

Example 6

The procedure was analogous to Example 3, but the metallocene component was a mixture of 11.9 mg (0.023 mmol) of diphenylmethylene(9-fluorenyl)(cyclopentadienyl)-

zirconium chloride and 12.9 mg (0.030 mmol) of dimethylmethylene(9-fluorenyl)(cyclopentadienyl)zirconium dichloride in 15 cm^3 of the toluene solution of methylaluminoxane. 2.05 kg of polypropylene, were obtained, corresponding to a metallocene mixture activity of 82.7 kg PP/g of metallocene mixture × h.
VN = 291 cm^3/g; M_w = 215,500 g/mol, M_w/M_n = 5.0 bimodal; SI = 96.1%.

Example 7

Example 6 was repeated, but 11.9 mg (0.023 mmol) and 6.5 mg (0.015 mmol) of the metallocenes were used. 1.35 kg of polypropylene were obtained, corresponding to 73.0 kg of PP/g of metallocene mixture × h.
VN = 353 cm^3/g; M_w = 285,500 g/mol, M_w/M_n = 5.4 bimodal; SI = 96.8%.

Example 8

Example 6 was repeated, but 6.0 mg (0.011 mmol) and 12.9 mg (0.030 mmol) of the metallocenes were used. 1.35 kg of polypropylene were obtained, corresponding to 71.4 kg of PP/g of metallocene mixture × h.
VN = 226 cm^3/g; M_w = 168,500 g/mol, M_w/M_n = 4.7, bimodal; SI = 96.0%.

Example 9

Example 6 was repeated, but 20.0 mg (0.036 mmol) and 4.4 mg (0.010 mmol) of the metallocenes were used. 1.87 kg of polypropylene were obtained, corresponding to 76.6 kg of PP/g of metallocene mixture × h.
VN = 423 cm^3/g; M_w = 327,000 g/mol, M_w/M_n = 5.9, SI = 96.6%.

Example 10

Example 6 was repeated, but 4.0 mg (0.007 mmol) and 16.3 mg (0.038 mmol) of the metallocenes were used. 1.45 kg of polypropylene were obtained, corresponding to 71.4 kg of PP/g of metallocene mixture × h.
VN = 167 cm^3/g; M_w = 110,000 g/mol, M_w/M_n = 4.0;

VN = 167 cm^3/g; M_w = 110,000 g/mol, M_w/M_n = 4.0;
SI = 95.9%.

Example 11

A dry 150 dm^3 reactor was flushed with nitrogen and filled at 20°C with 80 dm^3 of a gasoline fraction with the aromatics removed and with a boiling range of 100-120°C. The gas space was then flushed free from nitrogen by injecting 2 bar of propylene and releasing the pressure and repeating this cycle four times.

50 l of liquid propylene were added, and 320 cm^3 of a toluene solution of methylaluminoxane (corresponding to 500 mmol of Al, molecular weight 1180 g/mol according to cryoscopic determination), and the reactor contents were heated to 40°C. Hydrogen was metered in to give a hydrogen content in the gas space of the reactor of 0.1% by volume, and this content was then maintained during the entire polymerization time by topping up (on-line gas chromatography).

19.1 mg (0.039 mmol) of phenyl(methyl)methylene(9-fluorenyl)(cyclopentadienyl)zirconium dichloride and 21.5 mg (0.039 mmol) of diphenylmethylene(9-fluorenyl)(cyclopentadienyl)zirconium dichloride were mixed, and the solid was dissolved in 96 ml of a toluene solution of methylaluminoxane (corresponding to 150 mmol of Al) and, after 15 minutes, the solution was introduced into the reactor. The polymerization system was kept at 40°C for 5 hours by cooling. The polymerization was terminated by addition of 2 bar of CO_2 gas, and the polymer formed was separated from the suspension medium in a pressure filter. The product is dried for 24 hours at 80°C/200 mbar. 15.3 kg of polymer powder were obtained, corresponding to an activity of the metallocene mixture of 75.2 kg of PP/g of metallocene mixture × h.

VN = 523 cm^3/g; M_w = 368,000 g/mol; M_w/M_n = 4.2 bimodal;
SI = 97.4%.

Example 12

Example 11 was repeated, but 19.1 mg (0.039 mmol) and 11.0 mg (0.020 mmol) of the metallocenes were used and the polymerization temperature was 37°C. 9.7 kg of polymer powder were obtained, corresponding to an activity of 64.5 kg of PP/g of metallocene mixture × h.
VN = 428 cm^3/g; M_w = 326,000 g/mol; M_w/M_n = 3.4;
SI = 97.2%.

Example 13

Example 11 was repeated, but 6.0 mg (0.012 mmol) and 12.4 mg (0.022 mmol) of the metallocenes were used and the polymerization time was 7.5 hours. 9.5 kg of polymer powder were obtained, corresponding to an activity of 68.8 kg of PP/g of metallocene mixture × h.
VN = 618 cm^3/g; M_w = 457,000 g/mol; M_w/M_n = 3.4 bimodal;
SI = 97.0%.

Example 14

Example 11 was repeated, but 20.0 mg (0.040 mmol) and 4.8 mg (0.009 mmol) of the metallocenes were used. The polymerization temperature was 35°C. 8.85 kg of polymer powder were obtained, corresponding to an activity of 71.4 kg of PP/g of metallocene mixture × h.
VN = 321 cm^3/g; M_w = 223,500 g/mol; M_w/M_n = 3.1;
SI = 96.5%.

Example 15

Example 11 was repeated, but 7.9 mg (0.016 mmol) and 44.3 mg (0.080 mmol) of the metallocenes were used. No hydrogen was used, and the polymerization temperature was 44°C. 16.7 kg of polymer powder were obtained, corresponding to an activity of 63.9 kg of PP/g of metallocene mixture × h.
VN = 766 cm^3/g; M_w = 537,000 g/mol; M_w/M_n = 3.4;
SI = 97.0%.

Example 16

A dry 24 dm^3 reactor was flushed with nitrogen and charged with 12 dm^3 of liquid propylene and with 35 cm^3 of

a toluene solution of methylaluminoxane (corresponding to 52 of mmol Al, mean degree of oligomerization n = 18). The contents were stirred at 30°C for 30 minutes. In parallel, 6.0 mg (0.011 mmol) of diphenylmethylene(9-fluorenyl)(cyclopentadienyl)zirconium dichloride, 5.0 mg (0.010 mmol) of phenyl(methyl)methylene(9-fluorenyl)-(cyclopentadienyl) zirconium dichloride and 6.0 mg (0.014 mmol) of dimethylmethylene(9-fluorenyl)(cyclopentadienyl)zirconium dichloride as a mixture of solids were dissolved in 13.5 cm^3 of a toluene solution of methylaluminoxane (20 mmol of Al). After 30 minutes, the violet-red solution was introduced into the reactor, and the polymerization system was warmed to 60°C over the course of 5 minutes by supply of heat and kept at this temperature for 2 hours.

The polymerization was terminated by addition of 1 mol of CO_2 gas. 2.3 kg of polymer product were obtained. The activity was thus 67.6 kg of PP/g of metallocene mixture × h.

VN = 272 cm^3/g; M_w = 212,500 g/mol; M_w/M_n = 3.6; SI = 96.8%.

Example 17

Example 16 was repeated, but, in addition to propylene and methylaluminoxane solution, 10 dm^3(s.t.p.) of hydrogen and 100 g of ethylene were additionally metered into the reactor. The polymerization temperature was 50°C. Under these polymerization conditions, 2.10 kg of polymer product were obtained, corresponding to an activity of 61.8 kg of PP/g of metallocene mixture × h. VN = 330 cm^3/g; M_w = 205,500 g/mol; M_w/M_n = 3.9; 4.3% of ethylene content, SI = 96.0%.

Example 18

A dry 16 dm^3 reactor was flushed with nitrogen and charged with 10 dm^3 of liquid propylene and with 30 cm^3 of a toluene solution of methylaluminoxane (corresponding to 40 mmol of Al, mean degree of oligomerization of the methylaluminoxane was n = 20). The contents were stirred

at 30°C for 10 minutes. In parallel, 8.3 mg (0.015 mmol) of diphenylmethylene(9-fluorenyl)(cyclopentadienyl)zirconium dichloride and 7.4 mg (0.015 mmol) of phenyl(methyl)methylene(9-fluorenyl)(cyclopentadienyl)-zirconium dichloride were dissolved in 15 cm^3 of a toluene solution of methylaluminoxane (20 mmol of Al), and the solution was metered into the reactor after 10 minutes. The polymerization temperature was kept at 45°C for 6.5 hours. The polymerization was terminated by rapidly removing excess propylene in gas form. 1.95 kg of polymer product were obtained, and the polymerization activity was 19.1 kg of PP/g of metallocene mixture × h. VN = 556 cm^3/g; M_w = 427,500 g/mol; M_w/M_n = 3.9; SI = 97.6%.

Example 19

A dry 16 dm^3 reactor was flushed with nitrogen and charged with 24 dm^3(s.t.p.) (corresponding to 1.5 bar) of hydrogen, 10 dm^3 of liquid propylene and with 30 cm^3 of a toluene solution of methylaluminoxane (corresponding to 40 mmol of Al, mean degree of oligomerization of the methylaluminoxane was n = 20). The contents were stirred at 30°C for 15 minutes. In parallel, 8.0 mg (0.014 mmol) of diphenylmethylene(9-fluorenyl)(cyclopentadienyl)zirconium dichloride and 8.0 mg (0.016 mmol) of phenyl(methyl)methylene(9-fluorenyl)(cylcopentadienyl)-zirconium dichloride were dissolved in 7.5 cm^3 of a toluene solution of methylaluminoxane (10 mmol of Al), and the solution was metered into the reactor after 15 minutes. The polymerization temperature was adjusted to 60°C and kept at this temperature for 1 hour by cooling.

1.30 kg of polymer product were obtained, corresponding to an activity of 81.3 kg of PP/g of metallocene mixture × h.
VN = 165 cm^3/g; M_w = 116,800 g/mol; M_w/M_n = 3.0; SI = 96.8%.

Example 20

The procedure was as in Example 19, but 40 dm^3 (s.t.p.) (2.5 bar) of hydrogen were used and the metallocene mixture comprised 8.0 mg (0.014 mmol) of diphenylmethylene(9-fluorenyl)(cyclopentadienyl)zirconium dichloride and 9.0 mg (0.021 mmol) of dimethylmethylene(9-fluorenyl)(cyclopentadienyl)zirconium dichloride. The polymerization temperature was 70°C. 3.23 kg of polymer product were obtained, corresponding to an activity of 190.5 kg of PP/g of metallocene mixture × h.
VN = 105 cm^3/g; M_w = 68,600 g/mol; M_w/M_n = 3.0; SI = 96.0%.

Example 21

The procedure was as in Example 20, but only 16 dm^3 (s.t.p.) (1 bar) of hydrogen were used, and the polymerization temperature was 65°C. 2.54 kg of polymer product were obtained, corresponding to an activity of 149.4 kg of PP/g of metallocene mixture × h.
VN = 182 cm^3/g; M_w = 128,500 g/mol; M_w/M_n = 3.4; SI = 96.5%.

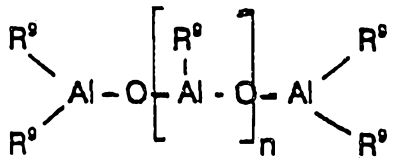
Example 22

The procedure was as in Example 19, but only 16 dm^3 (s.t.p.) (1 bar) of hydrogen were used. Instead of 30 cm^3 of the toluene solution of methylaluminoxane, 20 mmol of trimethylaluminium (as a 20% strength by weight solution in toluene) were introduced into the reactor, and the polymerization temperature was 55°C and the polymerization duration was 3 hours. 1.43 kg of polymer product were obtained, corresponding to an activity of 29.7 kg of PP/g of metallocene mixture × h.
VN = 184 cm^3/g; M_w = 130,500 g/mol; M_w/M_n = 3.2; SI = 97.1%.

PATENT CLAIMS:

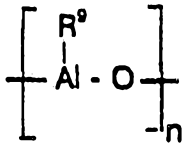
THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A process for the preparation of a syndiotactic polyolefin which has a molecular weight distribution M_w/M_n of ≥ 3.0 and which may be monomodal, bimodal or multimodal, by polymerization or copolymerization of an olefin of the formula $R^aCH=CHR^b$ in which R^a and R^b are identical or different and are a hydrogen atom or a alkyl radical having 1 to 14 carbon atoms, or R^a and R^b, together with the atoms connecting them, can form a ring, at a temperature of from -60 to 200°C, at a pressure of from 0.5 to 100 bar, in solution, in suspension or in the gas phase, in the presence of a catalyst comprising a transition-metal component (metallocene) and an aluminoxane of the formula II



(II)

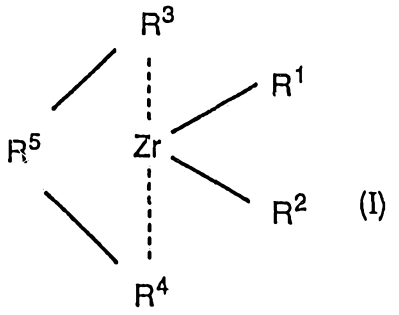
for the linear type and/or of the formula III



(III)

for the cyclic type, where, in the formulae II and III, the radicals R^9 may be identical or different and are a C_1-C_6-alkyl group, a C_1-C_6-fluoroalkyl group, a C_6-C_{18}-aryl group, a C_6-C_{18}-fluoroaryl group or a hydrogen, and n is an integer from 0 to 50, or, instead of the aluminoxane, comprises a mixture of an aluminoxane of the formula II and/or of the formula III with a compound AlR^9_3, which comprises using, as the transition-metal component, at least 2

metallocenes of the formula I

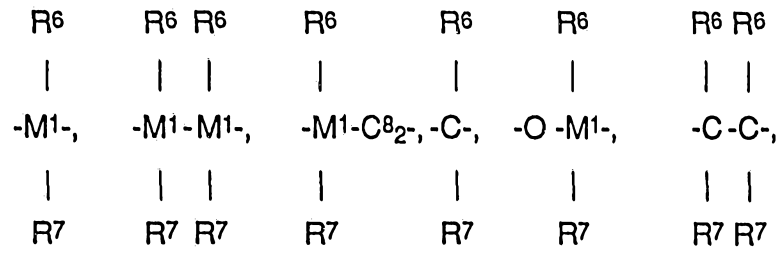


(I)

which are stereorigid and whose moiety formed by Zr and the substituents R^1 and R^2 has C_s symmetry or slightly distorted C_s symmetry as hereinbefore defined, and in which R^1 and R^2 are identical or different and are a hydrogen atom, a halogen atom, a C_1-C_{10}-alkyl group, a C_1-C_{10}-alkoxy group, a C_6-C_{10}-aryl group, a C_2-C_{10}-aryloxy group, a C_2-C_{10}-alkenyl group, a C_7-C_{40}-arylalkyl group, a C_7-C_{40}-alkylaryl group or a C_8-C_{40}-arylalkenyl group,

R^3 and R^4 are different and are monocyclic or polycyclic hydrocarbon radicals which can form a sandwich structure together with the central atom Zr,

R^5 is a single- or multimembered bridge which links the radicals R^3 and R^4 and is



=BR^6, =AlR^6, -GE-, -Sn, -O-, -S-, =SO, =SO_2, =NR^6, =CO, =PR^6 or P(O)R^6, where R^6, R^7 and R^8 are identical or different and are a hydrogen atom, a halogen atom, a C_1-C_{10}-alkyl group, a C_1-C_{10}-fluoroalkyl group, a C_6-C_{10}-fluoroaryl group, a C_6-C_{10}-aryl group, a C_1-C_{10}-alkoxy group, a C_2-C_{10}-alkenyl group, a C_7-C_{40}-arylalkyl group, a C_8-C_{40}-arylalkenyl group or a C_7-C_{40}-alkylaryl

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group, or R^6 and R^7 or R^6 and R^8, together with the atoms connecting them, in each case form a ring, and M^1 is silicon, germanium or tin.

2. The process as claimed in claim 1, wherein, in the formula I, the substituents R^1 and R^2 are chlorine.

3. The process as claimed in claim 1 or 2, wherein the metallocenes of the formula I are (arylalkylidene)(9-fluorenyl)(cyclopentadienyl)zirconium dichloride, (diarylmethylene)(9-fluorenyl)(cyclopentadienyl)zirconium dichloride and/or (dialkylmethylene)(9-fluorenyl)(cyclopentadienyl)zirconium dichloride.

4. The process as claimed in one or more of claims 1 to 3, wherein the metallocenes of the formula I are (methyl(phenyl)methylene)(9-fluorenyl)(cyclopentadienyl)zirconium dichloride, (diphenylmethylene)(9-fluorenyl)(cyclopentadienyl)zirconium dichloride and/or (dimethylmethylene)(9-fluorenyl)-(cyclopentadienyl)zirconium dichloride.

5. The process as claimed in one or more of claims 1 to 4 wherein propylene is polymerized.

DATED this 25th day of May 1992.

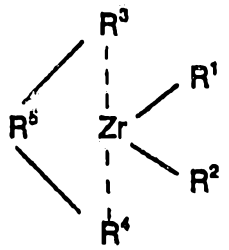
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ABSTRACT OF THE DISCLOSURE

Process for the preparation of syndiotactic polyolefins having a broad molecular weight distribution

Syndiotactic polyolefins having a molecular weight distribution M_w/M_n of ≥ 3 and which may be monomodal, bimodal or multimodal are obtained by polymerization or copolymerization of olefins of the formula RCH=CHR, in which a catalyst system comprising an aluminoxane and a transition-metal component (metallocene) is used, the transition-metal component comprising at least 2 metallocenes of the formula



(I)

which are stereorigid and whose moiety formed by Zr and the substituents R^1-R^4 has C_n symmetry or slightly distorted C_n symmetry.