(CONVENTION. By one or more persons and/or a Company.) Form 4.

COMMONWEALTH OF AUSTRALIA

Patents Act 1952-1969 641638

CONVENTION APPLICATION FOR A PATENT

(1) Here insert (in full) Name or Names of Applicant or Applicants, followed by Address(es).

~~I~~/We (1) HOECHST AKTIENGESELLSCHAFT, of D-6230 Frankfurt am Main 80, Federal Republic of Germany.

(2) Here insert Title of Invention.

hereby apply for the grant of a Patent for an invention entitled: (2) PROCESS FOR THE PREPARATION OF A SYNDIOTACTIC POLYOLEFIN

which is described in the accompanying complete specification. This applications is a Covention application and is based on the application numbered (3) P 39 07 964.3

(3) Here insert number(s) of basic application(s).

(4) Here insert Name of basic Country or Countries, and basic date or dates.

for a patent or similar protection made in (4) Federal Republic of Germany on 11th March, 1989.

~~My~~/Our address for service is WATERMARK PATENT & TRADEMARK ATTORNEYS 290 Burwood Road, Hawthorn, Victoria, Australia.

DATED this 8th day of March, 1990

F014990 09/03/90

(5) Signature(s) of Applicant(s) or Seal of Company and Signatures of its Officers as prescribed by its Articles of Association.

(5) HOECHST AKTIENGESELLSCHAFT

By: D.B. MISCHLEWSKI

Registered Patent Attorney

To: THE COMMISSIONER OF PATENTS.

89170 8V

COMMONWEALTH OF AUSTRALIA - Patents Act 1952

DECLARATION IN SUPPORT OF A CONVENTION APPLICATION UNDER PART XVI., FOR A PATENT

In support of the Convention application made under Part XVI. of the Patents Act 1952 by HOECHST AKTIENGESELLSCHAFT D-6230 Frankfurt am Main 80, Federal Republic of Germany

for a patent for an invention entitled:

Process for the preparation of a syndiotactic polyolefin

~~I~~/We, Ulrich Tergau, Am Dornbusch 3, D-6239 Eppstein/Taunus
Franz Lapice, Sandweg 2, D-6233 Kelkheim (Taunus)) Fed.Rep.ofGermany

do solemnly and sincerely declare as follows:

1. We are authorized by HOECHST AKTIENGESELLSCHAFT the applicant/~~s~~ for the patent to make this declaration on its/~~their~~ behalf.

2. The basic application/s as defined by Section 141 of the Act was/~~were~~ made by HOECHST AKTIENGESELLSCHAFT

Federal Republic of Germany P 39 07 964.3 of March 11, 1989

3.

1) Andreas Winter, Gundelhardtstraße 2, D-6233 Kelkheim/Taunus
2) Jürgen Rohrmann, Die Ritterwiesen 10, D-6237 Liederbach
3) Martin Antberg, Sachsenring 10, D-6238 Hofheim am Taunus
4) Volker Dolle, Hattersheimer Straße 15, D-6233 Kelkheim/Taunus
5) Walter Spaleck, Sulzbacher Straße 63, D-6237 Liederbach
1)-5) Fed.Rep.of Germany

~~is~~/are the actual inventor/s of the invention and the facts upon which HOECHST AKTIENGESELLSCHAFT is/~~are~~ entitled to make the application are as follows:
The said HOECHST AKTIENGESELLSCHAFT is/~~are~~ the assignee/~~s~~ of the said inventor/s

4. The basic application/~~s~~ referred to in paragraph 2 of this Declaration was/~~were~~ the the first application/~~s~~ made in a Convention country in respect of the invention the subject of the application.

Dated Frankfurt am Main, Fed.Rep.of Germany, January 16, 1990

HOECHST AKTIENGESELLSCHAFT

ppa. Tergau i.V. Lapice

To the Commissioner of Patents

AU9051179

(12) PATENT ABRIDGMENT (11) Document No. AU-B-51179/90
(19) AUSTRALIAN PATENT OFFICE (10) Acceptance No. 641638

(54) Title
PROCESS FOR THE PREPARATION OF A SYNDIOTACTIC POLYOLEFIN

International Patent Classification(s)
(51)[5] C08F 110/06 C08F 004/642

(21) Application No. : 51179/90 (22) Application Date : 09.03.90

(30) Priority Data

(31) Number	(32) Date	(33) Country
3907964	11.03.89	DE GERMANY

(43) Publication Date : 13.09.90

(44) Publication Date of Accepted Application : 30.09.93

(71) Applicant(s)
HOECHST AKTIENGESELLSCHAFT

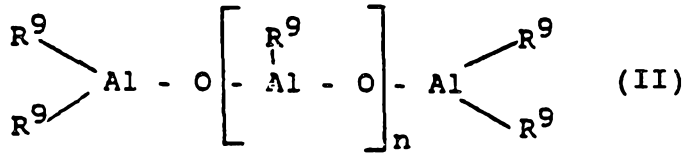
(72) Inventor(s)
ANDREAS WINTER; JURGEN ROHRMANN; MARTIN ANTBERG; VOLKER DOLLE; WALTER SPALECK

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

(56) Prior Art Documents
AU 51181/90 C08F 110/06
AU 39056/89 C08F 110/06
AU 31222/89 C08F 110/06

(57) Claim

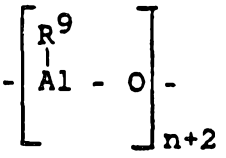
1. A process for the preparation of a syndiotactic polyolefin by polymerization or copolymerization of an olefin of the formula $R^aCH=CHR^b$, in which R^a and R^b are identical or different and denote a hydrogen atom or an alkyl radical having 1 to 28 carbon atoms, or R^a and R^b, with the atoms joining them, can form a ring, at a temperature of -60 to 200°C under a pressure of 0.5 to 100 bar in solution, in suspension or in the gas phase in the presence of a catalyst which consists of a metallocene as the transition metal component and an aluminoxane of the formula II



(II)

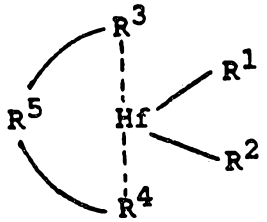
.../2

for the linear type and/or of the formula III



(III)

for the cyclic type, in which, in the formulae II and III, R^8 denotes a C_1-C_6-alkyl group or a C_6-C_{10}-aryl group or benzyl and n is an integer from 2 to 50, which comprises carrying out the polymerization in the presence of a catalyst, the transition metal component of which is a compound of the formula I



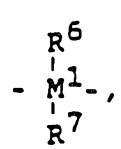
(I)

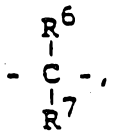
in which

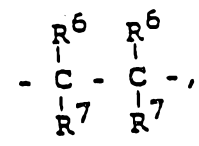
R^1 and R^2 are identical or different and denote a hydrogen atom, a halogen atom, a C_1-C_{10}-alkyl group, C_1-C_{10}-alkoxy group, C_6-C_{10}-aryl group, a C_6-C_{40}-arylalkyl group, a C_7-C_{40}-alkylaryl group or a C_8-C_{40}-arylalkenyl group,

R^3 and R^4 are different and denote a mono- or polynuclear hydrocarbon radical, which can form a sandwich structure with the hafnium,

R^5 is







in which R^6 and R^7 are identical or different and denote a hydrogen atom, a halogen atom, a C_1-C_{10}-alkyl group, a C_1-C_{10}-fluoroalkyl group, a C_8-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 in each case with the atoms joining them, form a ring, and M^1 is silicon.

Form 10

COMMONWEALTH OF AUSTRALIA

PATENTS ACT 1952-69

COMPLETE SPECIFICATION

(ORIGINAL)

641638

Class Int. Class

Application Number:
Lodged:

Complete Specification Lodged:
Accepted:
Published:

Priority :

Related Art :

Name of Applicant : HOECHST AKTIENGESELLSCHAFT

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

Actual Inventor : ANDREAS WINTER, JURGEN ROHRMANN, MARTIN ANTBERG, VOLKER DOLLE and WALTER SPALECK.

Address for Service : **WATERMARK PATENT & TRADEMARK ATTORNEYS.**
LOCKED BAG NO. 5, HAWTHORN, VICTORIA 3122, AUSTRALIA

Complete Specification for the invention entitled:

PROCESS FOR THE PREPARATION OF SYNDIOTACTIC POLYOLEFIN

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

Description

Process for the preparation of a syndiotactic polyolefin

The invention relates to a novel process which can be employed on a large industrial scale for the preparation of a syndiotactic polyolefin.

Syndiotactic polyolefins, in particular syndiotactic polypropylene, are known per se. However, it has not yet been possible to prepare such polymers in an adequate yield under polymerization conditions which are of interest industrially. Thus, it is known that syndiotactic polypropylene can be prepared by polymerization of propylene at -78°C in the presence of a catalyst system consisting of VCl_4, anisole, heptane and diisobutylaluminum chloride (compare B. Lotz et al., Macromolecules 21, (1988), 2375). However, the syndiotactic index (= 76.9%) and the yield (= 0.16%) are too low.

It is furthermore known that a syndiotactic polypropylene having a narrow molecular weight distribution can be obtained in a significantly improved yield with the aid of a catalyst consisting of isopropylene(cyclopentadienyl)(1-fluorenyl)-zirconium dichloride or isopropylene-(cyclopentadienyl)(1-fluorenyl)-hafnium dichloride and a methylaluminoxane at a temperature of 25 to 70°C (compare J.A. Ewen et al., J. Am. Chem. Soc., 110 (1988), 6255). Nevertheless, the molecular weight of the polymer which can be achieved by means of the zirconium compound is still too low. The syndiotactic indices which can be achieved are moreover still in need of improvement.

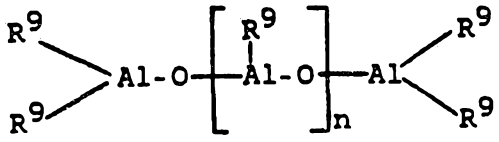
Although the narrow molecular weight distributions are suitable for injection molding and precision injection molding, a medium to broad molecular weight distribution would be advantageous for deep drawing, extrusion, hollow body blow molding, plate casting and the production of films.

It is known that the polymerization of ethylene in the presence of two or more metallocene catalysts simultaneously can produce polyethylene having a broad molecular weight distribution (compare EP 128,045). However, because several catalyst systems are used, the polymer is of poor homogeneity. The catalysts described moreover produce only atactic polymer, which is of only minor interest industrially, on polymerization of 1-olefins.

The object was to discover a process which produces a highly syndiotactic polyolefin of very high molecular weight and broad molecular weight distribution.

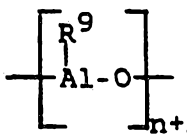
It has been found that the object can be achieved by using special hafnocene catalyst.

The invention thus relates to a process for the preparation of a syndiotactic polyolefin 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 denote a hydrogen atom or an alkyl radical having 1 to 28 carbon atoms, or R^a and R^b, with the atoms joining them, can form a ring, at a temperature of -60 to 200°C under a pressure of 0.5 to 100 bar in solution, in suspension or in the gas phase in the presence of a catalyst which consists of a metallocene as the transition metal component and an aluminoxane of the formula II



(II)

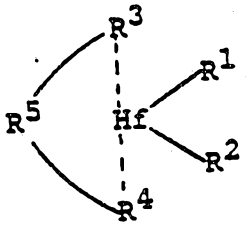
for the linear type and/or of the formula III



(III)

for the cyclic type, in which, in the formulae II and

III, R^9 denotes a C_1-C_6-alkyl group or a C_1-C_6-aryl group or benzyl and n is an integer from 2 to 50, which comprises carrying out the polmerization in the presence of a catalyst, the transition metal component of which is a compound of the formula I



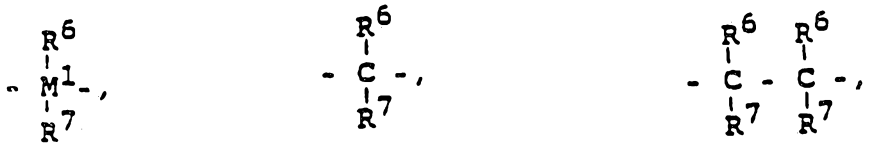
(I)

in which

R^1 and R^2 are identical or different and denote 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 denote a mono- or polynuclear hydrocarbon radical, which can form a sandwich structure with the hafnium,

R^5 is

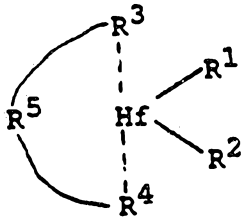


in which R^6 and R^7 are identical or different and denote a hydrogen atom, a halogen atom, a C_1-C_{10}-alkyl group, a C_1-C_{10}-fluoroalkyl group, a C_8-C_{10}-fluoroaryl group, a C_6-C_{10}-aryl group, a C_1-C_{10}-alkoxy group, a C_2-C_{10}-alkenyl group, a C_7-C_{40}-arylalkyl group, a C_8-C_{40}-arylalkenyl group or a C_7-C_{40}-alkylaryl group, or R^6 and R^7 in each case with the atoms joining them, form a ring, and

M^1 is silicon.

AUSTRALIAN PATENT OFFICE

The catalyst to be used for the process according to the invention consists of an aluminoxane and a metallocene of the formula I

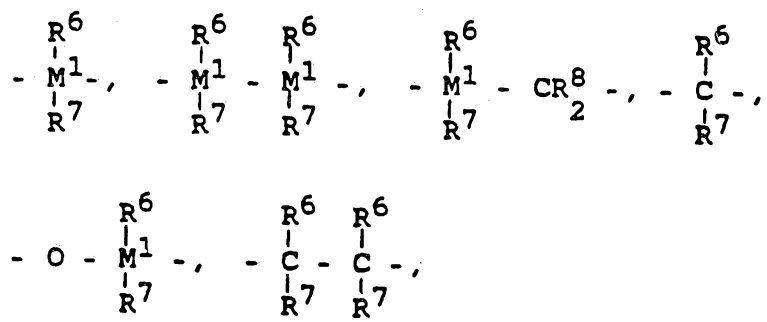


(I)

wherein R^1 and R^2 are identical or different and denote 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 denote a mono- or polynuclear hydrocarbon radical, which can form a sandwich structure with the hafnium. R^3 and R^4 are preferably fluorenyl and cyclopentadienyl, it also being possible for the fluorenyl or cyclopentadienyl base structures additionally to carry substituents.

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



$= BR^6$, $= AlR^6$, -Ge-, -Sn-, -O-, -S-, $= SO$, $= SO_2$, $= NR^6$, $= CO$, $= PR^6$ or $= P(O)R^6$, in which R^6, R^7 and R^8 are identical or different and denote a hydrogen atom, a halogen

atom, preferably chlorine, a C_1-C_{10}-, preferably C_1-C_3-alkyl group, in particular a methyl group, a C_1-C_{10}-fluoroalkyl group, preferably a CF_3 group, a C_6-C_{10}-fluoroaryl group, preferably a 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 a 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, in each case together with the atoms joining them, 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 $=P(O)R^6$.

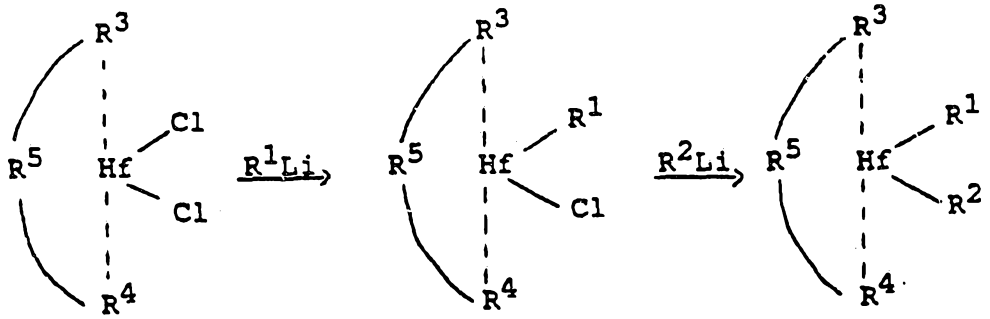
The metallocenes described above can be prepared in accordance with the following general equation:

H_2R^3 + ButylLi $\rightarrow$ HR^3Li

H_2R^4 + ButylLi $\rightarrow$ HR^4Li

$\xrightarrow{X\text{-}R^5\text{-}X}$

$HR^3\text{-}R^5\text{-}R^4H$ $\xrightarrow{2\ ButylLi}$ $LiR^3\text{-}R^5\text{-}R^4Li$ $\xrightarrow{HfCl_4}$

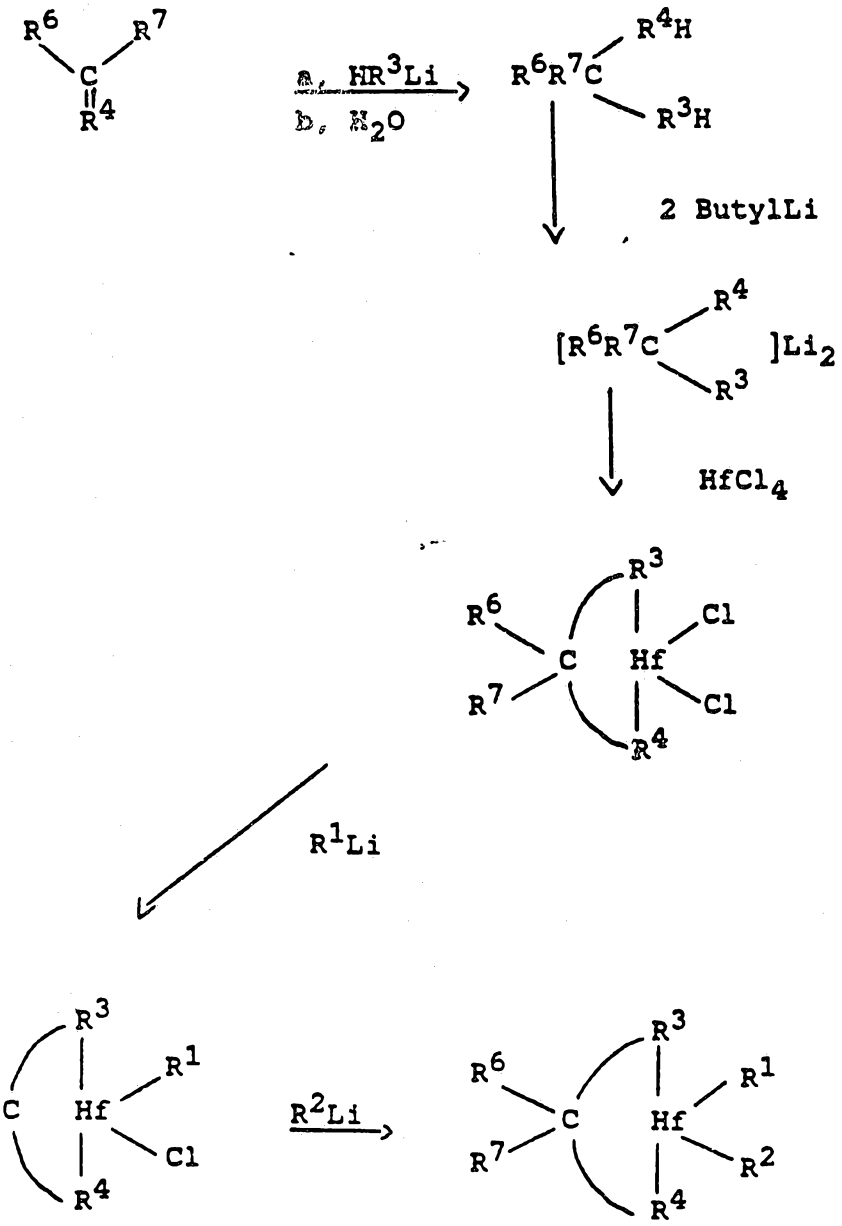


AUSTRALIAN PATENT OFFICE

(X = Cl, Br, J, O-Tosyl)

or

$H_2R^3 + ButylLi \longrightarrow HR^3Li$



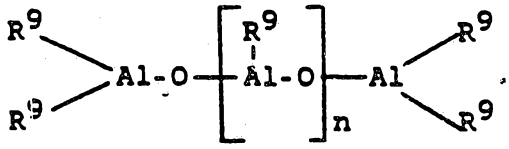
Metallocenes which are preferably employed are (arylalkylidene) (fluorenyl) (cyclopentadienyl)-hafnium dichloride and (diarylmethylene) (fluorenyl) (cyclopentadienyl)-hafnium dichloride. (Methyl(phenyl)methylene) (fluorenyl) (cyclopentadienyl)-hafnium dichloride and (diphenylmethylene)-(fluorenyl) (cyclopentadienyl)-hafnium dichloride are particularly preferred here. Other metallocenes which may be mentioned are:-

(diphenylsilyl) (fluorenyl) (cyclopentadienyl) hafnium dichloride (methyl(phenyl)silyl) (fluorenyl) (cyclopentadienyl) hafnium dichloride (dimethylsilyl) (fluorenyl) (cyclopentadienyl) hafnium dichloride (ethylene) (fluorenyl) (cyclopentadienyl) hafnium dichloride ((methyl)ethylene) (fluorenyl) (cyclopentadienyl) hafnium dichloride.

AUSTRALIAN PATENT OFFICE

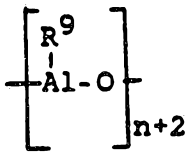
Metallocenes which are preferably employed are (arylalkylidene)(fluorenyl)(cyclopentadienyl)-hafnium dichloride and (diarylmethylene)(fluorenyl)(cyclopentadienyl)-hafnium dichloride. (Methyl(phenyl)methylene)(fluorenyl)(cyclopentadienyl)-hafnium dichloride and (diphenylmethylene)-(fluorenyl)(cyclopentadienyl)-hafnium dichloride are particularly preferred here.

The cocatalyst is an aluminoxane of the formula II



(II)

for the linear type and/or of the formula III



(III)

for the cyclic type. In these formulae, the radicals R^9 denote a C_1-C_6-alkyl group, preferably methyl, ethyl, isobutyl, butyl or neopentyl, or a C_6-C_{10}-aryl group, preferably phenyl or benzyl. Methyl is particularly preferred. n is an integer from 2 to 50, preferably 5 to 40. However, the exact structure of the aluminoxane is not known.

The aluminoxane can be prepared in various ways.

One possibility is careful addition of water to a dilute solution of an aluminum trialkyl by introducing in each case small portions of the solution of the aluminum trialkyl, preferably aluminum trimethyl, and the water into an initially introduced relatively large amount of an inert solvent and waiting for the evolution of gas to end between each addition.

In another process, finely powdered copper sulfate penta-

AUSTRALIAN PATENT OFFICE

hydrate is suspended in toluene in a glass flask, and aluminum trialkyl is added under an inert gas at about -20°C in an amount such that about 1 mole of $CuSO_4 \cdot 5H_2O$ is available for every 4 Al atoms. After slow hydrolysis, alkane being split off, the reaction mixture is left at room temperature for 24 to 48 hours, during which it must be cooled, if appropriate, so that the temperature does not rise above 30°C. The aluminoxane dissolved in the toluene is then filtered off from the copper sulfate and the solution is concentrated in vacuo. It is assumed that in this preparation process the low molecular weight aluminoxanes undergo condensation to higher oligomers, aluminum trialkyl being split off.

Aluminoxanes are furthermore obtained by a procedure in which aluminum trialkyl, preferably aluminum trimethyl, dissolved in an inert aliphatic or aromatic solvent, preferably heptane or toluene, is reacted with aluminum salts containing water of crystallization, preferably aluminum sulfate, at a temperature of -20 to 100°C. The volume ratio here between solvent and the aluminum alkyl used is 1:1 to 50:1 - preferably 5:1 - and the reaction time, which can be controlled by the splitting off of the alkane, is 1 to 200 hours - preferably 10 to 40 hours.

Of the aluminum salts containing water of crystallization, those which have a high content of water of crystallization are used in particular. Aluminum sulfate hydrate is particularly preferred, above all the compounds $Al_2(SO_4)_3 \cdot 16H_2O$ and $Al_2(SO_4)_3 \cdot 18H_2O$, with the particularly high water of crystallization content of 16 and 18 moles of H_2O/mole of $Al_2(SO_4)_3$ respectively.

Another variant for the preparation of aluminoxanes comprises dissolving aluminum trialkyl, preferably aluminum trimethyl, in heptane or toluene in the suspending agent which has been initially introduced into the polymerization vessel, preferably in the liquid monomer, and then reacting the aluminum compound with water.

In addition to the processes described above for the preparation of aluminoxanes, there are others which can be used. Regardless of the nature of the preparation, all the aluminoxane solutions have the common feature of a varying content of unreacted aluminum trialkyl which is in free form or as an adduct. This content has an influence on the catalytic activity which has not yet been clarified precisely and differs according to the metallocene compound employed.

It is possible for the metallocene to be preactivated before use in the polymerization reaction with an aluminoxane of the formula (II) and/or (III). The polymerization activity is in this way increased significantly and the grain morphology is improved.

The preactivation of the transition metal compound is carried out in solution. Preferably, in this procedure, the metallocene is dissolved in a solution of the aluminoxane in an inert hydrocarbon. An aliphatic or aromatic hydrocarbon is suitable as the inert hydrocarbon. Toluene is preferably used.

The concentration of the aluminoxane in the solution is in the range from about 1% by weight up to the saturation limit, preferably 5 to 30% by weight, in each case based on the total solution. The metallocene can be employed in the same concentration, but it is preferably employed in an amount of 10^{-4} - 1 mole per mole of aluminoxane. The preactivation time is 5 minutes to 60 hours, preferably 5 to 60 minutes. The reaction is carried out at a temperature of -78 to 100°C, preferably 0 to 70°C.

A significantly longer preactivation is possible, but this usually has neither an activity-increasing nor an activity-reducing effect, although it may be entirely appropriate for storage purposes.

The polymerization is carried out in a known manner in

solution, in suspension or in the gas phase, continuously or discontinuously, in one or more stages at a temperature of -60 to 200°C, preferably -30 to 100°C, in particular 0 to 80°C.

The total pressure in the polymerization system is 0.5 to 100 bar. The polymerization in the pressure range of 5 to 60 bar, which is of particular interest industrially, is preferred. Monomers of boiling points higher than the polymerization temperature are preferably polymerized under normal pressure.

In this reaction, the metallocene compound is used in a concentration, based on the transition metal, of 10^{-3} to 10^{-7}, preferably 10^{-4} to 10^{-6} mol of transition metal per dm^3 of solvent or per dm^3 of reactor volume. The aluminoxane is used in a concentration of 10^{-5} to 10^{-1} mol, preferably 10^{-5} 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 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; examples of these which may be mentioned are butane, pentane, hexane, heptane, isooctane, cyclohexane and methylcyclohexane.

A benzine or hydrogenated diesel oil fraction can furthermore be used. Toluene can also be used. The polymerization is preferably carried out in the liquid monomer.

Olefins of the formula $R^aCH = CHR^b$, in which R^a and R^b are identical or different and denote a hydrogen atom or an alkyl radical having 1 to 28 carbon atoms, it also being possible for R^a and R^b to be bonded as a ring, are polymerized or copolymerized. Examples of such olefins are

ethylene, propylene, 1-butene, 1-hexene, 4-methyl-1-pentene, 1-octene, norbornene or norbornadiene. Propylene, 1-butene and 4-methyl-1-pentene are preferred.

The molecular weight of the polymer can be regulated in a known manner. For example, the molecular weight can be regulated with excess trialkylaluminum, preferably trimethylaluminum present in the aluminoxane solution. Hydrogen is preferably used.

The polymerization can be of any desired duration, since the catalyst system to be used according to the invention exhibits only a slight time-dependent decrease in polymerization activity.

If the polymerization time is relatively long, the high molecular weight content in the polymer increases significantly. A longer residence time in the polymerization system is therefore advisable in order to achieve high average molecular weights. In order to achieve high molecular weights, it is advantageous to maintain a high polymerization temperature, since, in contrast to known processes, as the polymerization temperature increases in the polymerization system to be used according to the invention, a higher molecular weight has also simultaneously been found. Furthermore, a higher metallocene activity is also simultaneously achieved at a higher polymerization temperature. This means that lower residual ash contents are obtained in the polymer.

The molecular weight distribution is broad to bimodal at a higher polymerization temperature, and is narrow and monomodal at a lower temperature.

The polymers prepared according to the invention moreover generally exhibit a very high syndiotactic index of more than 90%; in this, the process according to the invention is significantly superior to the known processes.

The following examples are intended to illustrate the invention. In these examples

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 distribution

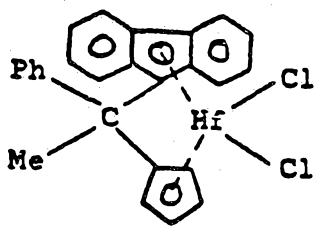
The molecular weight was determined by gel permeation chromatography.

SI = syndiotactic index, determined by ^{13}C-NMR spectroscopy
n_{syn} = average syndiotactic block length $(1+\frac{2rr}{mr})$

All the following working operations of metallocene synthesis were carried out under an inert gas atmosphere using absolute solvents.

Example 1

(Phenyl(methyl)methylene)(9-fluorenyl)(cyclopentadienyl)-hafnium dichloride



A solution of 67.8 mmol of lithium-fluorene in 50 cm^3 of tetrahydrofuran was added to a solution of 11.4 g (67.8 mmol) of 6-methyl-6-phenylfulvene in 40 cm^3 of tetrahydrofuran at room temperature. After the mixture had been stirred at room temperature for 2 hours, 60 cm^3 of water were added. The substance which precipitated out was filtered off with suction, washed with diethyl ether and dried under an oil pump vacuum. 19.1 g (84.2%) of 1-cyclopentadienyl-1-(9-fluorenyl)-ethylbenzene were

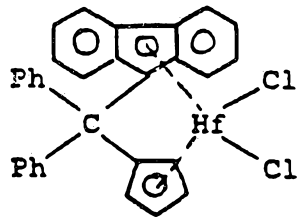
obtained (correct elemental analyses; ^{1}H-NMR spectrum). 10.0 g (19.9 mmol) of the compound were dissolved in 60 cm^3 of tetrahydrofuran and 26 cm^3 (65 mmol) of a 2.5 molar hexane solution of n-butyllithium were added at 0°C. After the mixture had been stirred for 15 minutes, the solvent was stripped off in vacuo. The dark red residue which remained was washed several times with hexane and dried under an oil pump vacuum. 15.6 g of the red dilithium salt were obtained as the tetrahydrofuran adduct which contained about 30% of tetrahydrofuran. A suspension of 4.78 g (14.9 mmol) of $HfCl_4$ in 70 cm^3 of CH_2CH_2 was reacted with 14.9 mmol of the dilithium salt and the reaction product was worked up. Crystallization at -35°C gave 2.6 g (30%) of the hafnocene dichloride compound as orange crystals.

Correct elemental analysis.

1 H-NMR spectrum (100 MHz, $CDCl_3$): 7.17 - 8.20 (m, 11 H, Flu-H,Ph-H), 6.87 (m, 1, Ph-H), 6.12 - 6.42 (m,3, Ph-H,CpH), 5.82, 5.67 (2xdd,2x1,Cp-H), 2.52 (s,3,CH_3).

Example 2

Diphenylmethylene(9-fluorenyl)(cyclopentadienyl)-hafnium dichloride



12.3 cm^3 (30.7 mmol) of a 2.5 molar hexane solution of n-butyllithium were slowly added to a solution of 5.10 g (30.7 mmol) of fluorene in 60 cm^3 of tetrahydrofuran at room temperature. 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, whereupon the solution became yellow-colored, and the mixture was extracted with ether. The ether phase was dried over $MgSO_4$ and concentrated and

the residue was left to crystallize at -35°C. 5.1 g (42%) of 1-cyclopentadienyl-1-(9-fluorenyl)-diphenylmethane were obtained as a beige powder. 1.25 g (3.15 mmol) of 1-cyclopentadienyl-1-(9-fluorenyl)-diphenylmethane were reacted with 6.3 mmol of butyllithium analogously to Example 1. The dilithium salt was reacted with 1.0 g (3.15 mmol) of $HfCl_4$ analogously to Example 1. Filtration of the orange reaction mixture over a G4 frit and extraction of the filtrate with 100 cm^3 of toluene gave 0.70 g (34%) of the hafnocene dichloride complex as a yellow-orange powder. Correct elemental analysis. The mass spectrum gave $M^+ = 644$.

^{1}H-NMR spectrum (100 MHz,$CDCl_3$): 6.85 - 8.25 (m,16,Flu-H,Ph-H), 6.37 (m,2,Ph-H), 6.31 (t,2,Cp-H), 5.75 (t,2,Cp-M).

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, average degree of oligomerization of the methylaluminoxane n = 20) were then added and the mixture was stirred for 15 minutes.

In parallel to this, 53.0 mg (0.082 mmol) of diphenylmethylene(fluorenyl)(cyclopentadienyl)-hafnium 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 brought to 60°C. Polymerization was carried out for 5 hours. 3.20 kg of polypropylene, corresponding to a metallocene activity of 12.0 kg of polypropylene/g of metallocene x hour, were obtained. VN = 1254 cm^3/g; $M_w = 2.34 \cdot 10^6$, M_n = 580,000, M_w/M_n = 4.0, bimodal molecular weight distribution; SI = 96.9%, n_{syn} = 39.4; melt flow index 230/5 ≤ 0.1 dg/minute.

Example 4

The procedure was analogous to Example 3, but 64.4 mg (0.10 mmol) of diphenylmethylene(fluorenyl)(cyclopentadienyl)-hafnium dichloride were employed, the polymerization temperature was 50°C and the polymerization time was 1 hour. 0.34 kg of polypropylene, corresponding to a metallocene activity of 5.3 kg of polypropylene/g of metallocene x hour, was obtained.
VN = 978 cm^3/g; $M_w = 2.01 \cdot 10^6$, $M_n = 0.61 \cdot 10^6$, $M_w/M_n = 3.3$, bimodal molecular weight distribution; SI = 97.0%, n_{syn} = 40.0; melt flow index 230/5 ≤ 0.1 dg/minute.

Example 5

The process was analogous to Example 3, but 126.4 mg (0.196 mmol) of diphenylmethylene(fluorenyl)(cyclopentadienyl)-hafnium dichloride were employed, the polymerization temperature was 30°C and the polymerization time was 2 hours. 0.35 kg of polypropylene, corresponding to a metallocene activity of 1.4 kg of polypropylene/g of metallocene x hour, were obtained.
VN = 487 cm^3/g; M_w = 672,500, M_n = 196,500, M_w/M_n = 3.4, monomodal molecular weight distribution; SI = 97.5%, n_{syn} = 48.0; melt flow index 230/5 = 0.1 dg/minute.

Examples 3 to 5 show that a high polymerization temperature must be used to achieve a high molecular weight. At the same time, at the higher polymerization temperature the polymerization activity of the metallocene catalyst system is advantageously higher.

Example 6

The procedure was analogous to Example 3, but 66.6 mg (0.114 mmol) of (phenyl(methyl)methylene)(fluorenyl)-(cyclopentadienyl)-hafnium dichloride were employed. 1.89 kg of polypropylene, corresponding to a metallocene activity of 5.7 kg of polypropylene/g of metallocene x

hour, were obtained.
VN = 603 cm^3/g; M_w = 806,000, M_n = 175,000, M_w/M_n = 4.6, the molecular weight distribution was bimodal; SI = 96.4%, n_{syn} = 38.0; melt flow index 230/5 ≤ 0.1 dg/minute.

Example 7

The procedure was analogous to Example 3, but 63.9 mg (0.11 mmol) of (phenyl(methyl)methylene)(fluorenyl)-(cyclopentadienyl)-hafnium dichloride were employed, the polymerization temperature was 50°C and the polymerization time was 1 hour. 0.17 kg of polypropylene, corresponding to a metallocene activity of 2.7 kg of polypropylene/g of metallocene x hour, was obtained.
VN = 380 cm^3/g; M_w = 434,000, M_n = 116,000, M_w/M_n = 3.7, the molecular weight distribution was bimodal; SI = 96.1%, n_{syn} = 37.0; melt flow index 230/5 = 0.24 dg/minute.

Example 8

The procedure was analogous to Example 3, but 110.3 mg (0.19 mmol) of (phenyl(methyl)methylene)(fluorenyl)-(cyclopentadienyl)-hafnium dichloride were employed and the polymerization temperature was 40°C. 0.65 kg of polypropylene, corresponding to a metallocene activity of 1.2 kg of polypropylene/g of metallocene x hour, was obtained.
VN = 576 cm^3/g; M_w = 837,500, M_n = 131,500, M_w/M_n = 6.4; the molecular weight distribution was bimodal; SI = 97.1%, n_{syn} = 40.0; melt flow index 230/5 < 0.1 dg/minute.

Example 9

The procedure was analogous to Example 3, but 151.1 mg (0.26 mmol) of (phenyl(methyl)methylene)(fluorenyl)-(cyclopentadienyl)-hafnium dichloride were employed and the polymerization temperature was 30°C. 0.35 kg of

polypropylene, corresponding to a metallocene activity of 0.5 kg of polypropylene/g of metallocene x hour, was obtained. VN = 251 cm^3/g; M_w = 280,500, M_n = 108,500, M_w/M_n = 2.6; the molecular weight distribution was monomodal; SI = 97.5%, n_{syn} = 49.4; melt flow index 230/5 = 1.1 dg/minute.

The examples show that a high polymerization temperature must be used to achieve the maximum possible molecular weight. At the same time, the activity of the metallocene catalyst is higher at a higher polymerization temperature than at a lower polymerization temperature. Example 8 shows that instead of a high polymerization temperature, a long polymerization time also leads to a high molecular weight.

Example 10

A dry 16 dm^3 reactor was flushed with nitrogen and filled with 1.6 Ndm^3 (corresponding to 0.1 bar) of hydrogen and with 10 dm^3 of liquid propylene. 30 cm^3 of a toluene solution of methylaluminumoxane (corresponding to 40 mmol of Al, average degree of oligomerization of the methylaluminumoxane n=20) were then added and the mixture was stirred for 15 minutes.

In parallel with this, 55.7 mg (0.087 mmol) of diphenylmethylene(fluorenyl)(cyclopentadienyl)-hafnium dichloride were dissolved in 15 cm^3 of a toluene solution of methylaluminoxane (20 mmol of Al).

After 15 minutes, the solution was metered into the reactor and the polymerization temperature was brought to 60°C. Polymerization was carried out for 1 hour. 1.0 kg of polypropylene, corresponding to a metallocene activity of 18.0 kg of polypropylene/g of metallocene x hour, was obtained.
VN = 745 cm^3/g; SI = 97.5%; M_w = 978,000, M_n = 251,500, M_w/M_n = 3.9; melt flow index 230/5 = < 0.1 dg/minute.

According to ^{13}C-NMR, the polymer chains had no unsaturated chain ends.

Example 11

The procedure was analogous to Example 10, but 48.7 mg (0.084 mmol) of (phenyl(methyl)methylene)(fluorenyl)-(cyclopentadienyl)-hafnium dichloride were employed. 1.91 kg of polypropylene, corresponding to a metallocene activity of 7.8 kg of polypropylene/g of metallocene x hour, were obtained.

VN = 492 cm^3/g; M_w = 697,500; M_n = 131,000; M_w/M_n = 5.3, the molecular weight distribution was bimodal; SI = 97.5%; melt flow index 230/5 = 0.1 dg/minute.

According to ^{13}C-NMR, the polymer chains had no unsaturated chain ends.

Example 12

The procedure was analogous to Example 10, but 40 dm^3 (corresponding to 2.5 bar) of hydrogen and 60.7 mg (0.104 mmol) of (phenyl(methyl)methylene)(fluorenyl)-(cyclopentadienyl)-hafnium dichloride were employed. 2.47 kg of polypropylene, corresponding to a metallocene activity of 8.1 kg of polypropylene/g of metallocene x hour, were obtained.

VN = 215 cm^3/g; M_w = 218,500; M_n = 75,500; M_w/M_n = 2.9; SI = 98.0%; melt flow index 230/5 = 8.1 dg/minute.

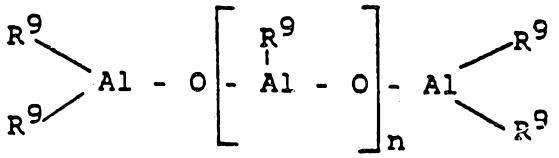
According to ^{13}C-NMR, the polymer chains had no unsaturated chain ends.

Examples 10 to 12 demonstrate the possibility of regulating the molecular weight by means of addition of hydrogen during the polymerization.

THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

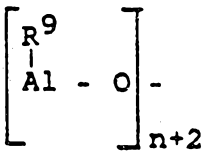
Patent Claims

1. A process for the preparation of a syndiotactic polyolefin 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 denote a hydrogen atom or an alkyl radical having 1 to 28 carbon atoms, or R^a and R^b, with the atoms joining them, can form a ring, at a temperature of -60 to 200°C under a pressure of 0.5 to 100 bar in solution, in suspension or in the gas phase in the presence of a catalyst which consists of a metallocene as the transition metal component and an aluminoxane of the formula II



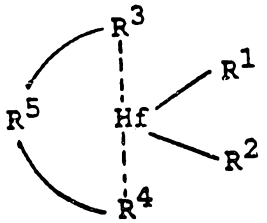
(II)

for the linear type and/or of the formula III



(III)

for the cyclic type, in which, in the formulae II and III, R^9 denotes a C_1-C_6-alkyl group or a C_6-C_{10}-aryl group or benzyl and n is an integer from 2 to 50, which comprises carrying out the polymerization in the presence of a catalyst, the transition metal component of which is a compound of the formula I



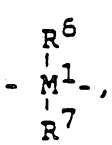
(I)

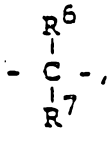
in which

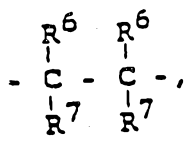
R^1 and R^2 are identical or different and denote a hydrogen atom, a halogen atom, a C_1-C_{10}-alkyl group, C_1-C_{10}-alkoxy group, C_6-C_{10}-aryl group, a C_6-C_{40}-arylalkyl group, a C_7-C_{40}-alkylaryl group or a C_8-C_{40}-arylalkenyl group,

R^3 and R^4 are different and denote a mono- or polynuclear hydrocarbon radical, which can form a sandwich structure with the hafnium,

R^5 is







in which R^6 and R^7 are identical or different and denote a hydrogen atom, a halogen atom, a C_1-C_{10}-alkyl group, a C_1-C_{10}-fluoroalkyl group, a C_8-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 in each case with the atoms joining them, form a ring, and M^1 is silicon.

2. The use of the syndiotactic polyolefin prepared as claimed in claim 1 for the production of films and shaped articles by extrusion, injection molding, blow molding or compression sintering.

DATED this 6th day of March 1992.

HOECHST AKTIENGESELLSCHAFT

WATERMARK PATENT & TRADEMARK ATTORNEYS
THE ATRIUM
290 BURWOOD ROAD
HAWTHORN VICTORIA 3122
AUSTRALIA

DBM/IAS/CH (DOC.10) AU5117990.WPC

AUSTRALIAN PATENT OFFICE