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| <p>(54) Title: CATALYST COMPONENT COMPRISING MAGNESIUM, TITANIUM, A HALOGEN AND AN ELECTRON DONOR, ITS PREPARATION AND USE</p> <p>(57) Abstract</p> <p>The invention relates to a process for the preparation of an olefin polymerization catalyst component, as well as a polymerization catalyst component and its use. In the process, a magnesium compound containing an alkoxy moiety, a dicarboxylic acid dihalide, and a titanium tetrahalide are reacted with each other. Good activity can be obtained easily by adding a reactive halogenated hydrocarbon during the process.</p>  |  |  |

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## Catalyst component comprising magnesium, titanium, a halogen and an electron donor, its preparation and use

5 The invention relates to a process for the preparation of an olefin polymerization catalyst component comprising a magnesium dihalide, a titanium tetrahalide, and a dicarboxylic acid diester as internal electron donor. The invention also relates to such a catalyst component and its use for the polymerization of  $\alpha$ -olefins such as propene.

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### Background of the invention

Generally, so called Ziegler-Natta catalyst components of the above kind have been prepared by reacting a magnesium halide-alcohol complex support with a titanium tetrahalide and an electron donor which usually is a phthalic acid diester. The preparation involves the use of large amounts of reagents and washing liquids, which are difficult to handle. Additionally, byproducts are formed, which cannot easily be regenerated or destroyed, but form an environmental problem.

20 For example, the preparation of a conventional polypropene catalyst component involves the reaction of a magnesium dichloride-alcohol complex support with titanium tetrachloride to give a surface layer of reactive  $\beta$ -magnesium dichloride as intermediate and hydrogen chloride and titanium alkoxy trichloride as byproducts. Then, the surface layer of reactive  $\beta$ -magnesium dichloride intermediate is activated with further titanium tetrachloride and optionally an internal electron donor to give said catalyst component (the treatment with a titanium halide such as titanium tetrachloride is henceforth called titanation). The result is an essentially inert magnesiumchloride based support covered with active sites based on titanium, chlorine and the optional internal electron donor.

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The titanium alkoxy trichloride byproduct formed in such a titanation is a catalyst poison and must be carefully removed by extensive washing using large amounts of titanium tetrachloride. Further, the titanium alkoxy trichloride must be carefully separated from the titanium tetrachloride washing liquid, if the latter is to be reused e.g. for activating the reactive  $\beta$ -magnesium dichloride. Finally, the titanium alkoxy trichloride is a hazardous waste material, which is difficult to dispose of.

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Thus, in a typical propene polymerization catalyst component preparation involving two titanations and three heptane washes, one mol of produced catalyst component (mol Mg) requires about 40 mol of titanium tetrachloride e.g. as washing liquid to be circulated, and produces as waste material an amount of about three mol of titanium alkoxy trichloride as well as about three mol of hydrogen chloride.

Sumitomo, EP 0 748 820 A1 (hereinafter referred to as "Sumitomo"), has prepared dialkoxy magnesium, reacted it with titanium tetrachloride to form an intermediate and then reacted the intermediate with phthalic acid dichloride to form a catalytically active propene polymerization catalyst component. The activity was raised by repeated titanations, as well as repeated washes with toluene and hexane. See page 10, lines 14 to 37, of said publication.

Said process of Sumitomo has avoided the reaction between the magnesium dichloride-alcohol complex and titanium tetrachloride, and thereby eliminated the formation of large amounts of catalytically poisonous titanium alkoxy trichloride byproduct. However, as much as four titanations and hydrocarbon treatments are still needed to give satisfactory catalytic activity.

## 20 Description of the invention

The purpose of the present invention is to provide a process which results in a catalyst component having satisfactory activity without producing harmful byproducts such as said titanium alkoxy trichloride or requiring the use of large amounts of titanation reagent and/or washing liquid.

The problem described above has now been solved with a novel process for the preparation of a catalyst component of the above type, which is mainly characterized by the steps of:

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(i) providing a magnesium compound (ab) containing an alkoxy moiety, selected from the group consisting of a magnesium dialkoxide, a complex containing a magnesium dihalide and an alcohol, and a complex containing a magnesium dihalide and a magnesium dialkoxide, and

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(ii) reacting said magnesium compound (ab) with at least one dicarboxylic acid dihalide (c) which forms said dicarboxylic acid diester as internal donor ED and has the formula (1):



5 wherein each R'' is a similar or different C<sub>1</sub>-C<sub>20</sub> hydrocarbyl group or both R''s form together with the two unsaturated carbons of the formula a C<sub>5</sub>-C<sub>20</sub> aliphatic or aromatic ring, and X' is a halogen, to give an intermediate (abc), and

(iii) reacting said intermediate (abc) with at least one titanium tetrahalide TiX''<sub>4</sub> (d) wherein X'' is a halogen,

10 (iv) recovering said catalyst component in crude form or recovering a precursor of said catalyst component, and

(v) optionally washing said crude catalyst component or said precursor, to give said catalyst component, and

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by adding and reacting in connection with the above step (ii) or (iii) at least one halogenated hydrocarbon (e) of the formula (2)



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wherein R''' is an n-valent C<sub>1</sub>-C<sub>20</sub> hydrocarbyl group, X''' is a halogen and n is an integer selected from 1, 2, 3 and 4.

25 It has thus been found that a high activity olefin polymerization catalyst comprising a magnesium halide, a titanium tetrahalide and a dicarboxylic acid diester as internal donor can be prepared without the above mentioned disadvantages by reacting a magnesium compound containing an alkoxy moiety with a dicarboxylic acid dihalide and a titanium tetrahalide and adding a reactive halogenated hydrocarbon.

30 Of the above mentioned steps (i) to (iii) preferably all are performed in solution. For dissolution of the reactants, one or several hydrocarbon solvents can be used, optionally together with the application of stirring and/or heating. Performing the process in a solution means that all reagent molecules can react with each other, thus forming a homogenous reaction product. Earlier processes which have been

performed by reacting a solid support with a titanium compound and an electron donor, see above, do not form homogenous reaction products.

5 The catalyst component is in step (iv) preferably recovered in solid form by precipitation. Precipitation in the present invention means that the reaction product formed in solution is recovered as a powder, the particles of which consist of similar molecules of that reaction product. The particles formed according to the present invention are thus homogenous, while the particles of earlier processes are more or less heterogenous (inert core + active surface).

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It is preferable if said first and second intermediates as well as the final product of the claimed process are separate compounds with an essentially stoichiometric composition. Often, they are complexes. A complex is, according to Römpps Chemie-Lexicon, 7. Edition, Franckh'sche Verlagshandlung, W. Keller & Co.,  
15 Stuttgart, 1973, page 1831, "a derived name of *compounds of higher order*, which originate from the combination of *molecules*, - unlike compounds of first order, in the creation of which atoms participate.

20 Reactive halogenated hydrocarbons (e) of the present invention are, e.g., monochloromethane, dichloromethane, trichloromethane (chloroform), tetrachloromethane, monochloroethane, 1,1-dichloroethane, 1,2-dichloroethane, 1,1,1-trichloroethane, 1,1,2-trichloroethane, 1,1,1,2-tetrachloroethane, 1,1,2,2-tetrachloroethane, pentachloroethane, hexachloroethane, 1-chloropropane, 2-chloropropane, 1,2-dichloropropane, 1,3-dichloropropane, 1,2,3-trichloropropane, 1-chlorobutane,  
25 2-chlorobutane, isobutyl chloride, tert.butyl chloride, 1,4-dichlorobutane, 1-chloropentane and 1,5-dichloropentane, as well as their corresponding compounds having other halogens. The chlorinated hydrocarbons of the invention may also be unsaturated, provided that the unsaturation does not act as catalyst poison in the final catalyst component.

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In the invention, it was found that the addition of a reactive halogenated hydrocarbon (e) during the process led to a significantly improved catalytic activity. In said reactive halogenated hydrocarbon (e) having the above formula (2), X''' is preferably chlorine.

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R''' is preferably a mono- or bivalent saturated C<sub>1</sub>-C<sub>10</sub> hydrocarbyl group. Preferably said reactive halogenated hydrocarbon (e) is a butyl chloride (BuCl) or a dichloroalkane like 1,4-dichlorobutane, more preferably tertiary butyl chloride or a

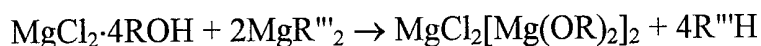
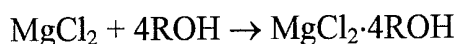
dichloroalkane like 1,4-dichlorobutane, most preferably a dichloroalkane like 1,4-dichlorobutane.

5 It was also found, that especially good results were obtained, if said reactive halogenated hydrocarbon (e) is added in an amount corresponding to a molar ratio  $Mg_{total\ added}/(e)$  of between 1:0.2 and 1:20, preferably between about 1:1 and about 1:4.

10 Said reactive halogenated hydrocarbon (e) can be added in step (ii) or (iii). Preferably it is added in connection with step (ii). This means that in the process, it is preferably added immediately before the dicarboxylic acid dihalide (c), together with it or immediately after it. As there is a possibility that the reactive halogenated hydrocarbon (e) may disturb the conversion of the dicarboxyl di-halide into said dicarboxylic acid diester donor, it is most preferably added immediately after the  
15 addition of the dicarboxylic acid dihalide (c). The symbols (ab) and (abc) may include the added or reacted reactive halogenated hydrocarbon (e). The symbols do not limit the reactants leading to the corresponding intermediates to (a), (b), (c) and (d).

20 The process according to the present invention starts with step (i), in which said magnesium compound (ab) containing an alkoxy moiety is provided. According to one embodiment, said complex of said magnesium dihalide and said magnesium dialkoxide as said magnesium compound (ab) is preferably a magnesium dichloride-magnesium alkoxide complex having the formula  $MgCl_2 \cdot [Mg(OR)_2]_t$ , wherein R is a  
25  $C_1$ - $C_{20}$  alkyl or a  $C_7$ - $C_{27}$  aralkyl, preferably a  $C_6$ - $C_{16}$  alkyl, and t is 1-6, preferably about 2. It is e.g. prepared by reacting magnesium dichloride  $MgCl_2$  with an alcohol ROH into an intermediate which is a magnesium dichloride/alcohol complex  $MgCl_2 \cdot (ROH)_{2t}$  and reacting the magnesium dichloride-alcohol complex with t mol of a magnesium dialkyl  $MgR''_2$ , wherein R'' is a hydrocarbyl group having 1 to 20  
30 carbon atoms.

Preferably, the complex of said magnesium dihalide and a magnesium dialkoxide as said alkoxy compound is a magnesium dichloride-dimagnesium dialkoxide complex having the formula  $MgCl_2 \cdot [Mg(OR)_2]_2$ , wherein R is a  $C_1$ - $C_{20}$  alkyl or a  $C_7$ - $C_{27}$   
35 aralkyl, preferably a  $C_6$ - $C_{16}$  alkyl. The complex may e.g. be prepared by reacting magnesium dichloride with an alcohol ROH and the obtained intermediate with a dialkyl magnesium  $R''_2Mg$  essentially as follows:



- 5 In the reaction between the magnesium dihalide, the alcohol and the dialkyl-  
magnesium, the molar ratio  $\text{MgCl}_2:\text{ROH}$  is preferably 1:1 to 1:8, most preferably  
1:2 to 1.5. The molar ratio  $\text{MgCl}_2 \cdot 4\text{ROH}:\text{MgR}''_2$  is preferably 1:1 to 1:4, most  
preferably about 1:2. The temperature is preferably about 50 °C to about 150 °C and  
the reaction time preferably about 2 h to about 8 h. A hydrocarbon solvent such as  
10 toluene may be present in the reaction.

The magnesium compound (ab) is usually titaniumless. Most preferably, the  
magnesium compound (ab) is provided by reacting an alkyl magnesium compound  
and/ or a magnesium dihalide with an alcohol. Thereby, at least one magnesium  
15 compound precursor (a), selected from the group consisting of a dialkyl magnesium  
 $\text{R}_2\text{Mg}$ , an alkyl magnesium alkoxide  $\text{RMgOR}$ , wherein each R is a similar or  
different  $\text{C}_1\text{-C}_{20}$  alkyl, and a magnesium dihalide  $\text{MgX}_2$ , wherein X is a halogen, is  
reacted with at least one alcohol (b), selected from the group consisting of  
monohydric alcohols  $\text{R}'\text{OH}$  and polyhydric alcohols  $\text{R}'(\text{OH})_m$ , wherein  $\text{R}'$  is an 1-  
20 valent or, respectively, an m-valent  $\text{C}_1\text{-C}_{20}$  hydrocarbyl group and m is an integer  
selected from 2, 3, 4, 5 and 6, to give said magnesium compound (ab).  $\text{R}'$  is the  
same or different in the formulas  $\text{R}'\text{OH}$  and  $\text{R}'(\text{OH})_m$ . By valence is understood the  
number of bonds that an atom can form (Stanley H. Pine, Organic Chemistry, 5.  
edition, McGraw-Hill, Inc., New York, 1987, page 10). The R of the dialkyl  
25 magnesium is preferably a similar or different  $\text{C}_4\text{-C}_{12}$  alkyl. Typical magnesium  
alkyls are ethylbutyl magnesium, dibutyl magnesium, dipropyl magnesium,  
propylbutyl magnesium, dipentyl magnesium, butylpentylmagnesium, butyloctyl  
magnesium and dioctyl magnesium. Typical alkyl-alkoxy magnesium compounds  
are ethyl magnesium butoxide, magnesium dibutoxide, butyl magnesium pentoxide,  
30 magnesium dipentoxide, octyl magnesium butoxide and octyl magnesium octoxide.  
Most preferably, on R is a butyl group and the other R of  $\text{R}_2\text{Mg}$  is an octyl group,  
i.e. the dialkyl magnesium compound is butyl octyl magnesium. When used as said  
magnesium compound precursor (a), the magnesium dihalide is preferably  
magnesium dichloride  $\text{MgCl}_2$ .

35

The alcohol (b) of step (i) may be a monohydric alcohol, a polyhydric (by definition  
including dihydric and higher alcohols) alcohol or a mixture of at least one  
monohydric alcohol and at least one polyhydric alcohol. Magnesium enriched

complexes can be obtained by replacing a part of the monohydric alcohol with the polyhydric alcohol.

Typical  $C_1$ - $C_5$  monohydric alcohols are methanol, ethanol, n-propanol, iso-  
5 propanol, n-butanol, iso-butanol, sec.butanol, tert.butanol, n-amyl alcohol, iso-amyl  
alcohol, sec.amyl alcohol, tert.amyl alcohol, diethyl carbinol, akt. amyl alcohol, sec.  
isoamyl alcohol, tert.butyl carbinol. Typical  $C_6$ - $C_{10}$  monohydric alcohols are  
hexanol, 2-ethyl-1-butanol, 4-methyl-2-pentanol, 1-heptanol, 2-heptanol,  
4-heptanol, 2,4-dimethyl-3-pentanol, 1-octanol, 2-octanol, 2-ethyl-1-hexanol,  
10 1-nonanol, 5-nonanol, diisobutyl carbinol, 1-decanol and 2,7-dimethyl-2-octanol.  
Typical  $>C_{10}$  monohydric alcohols are n-1-undecanol, n-1-dodecanol, n-1-  
tridecanol, n-1-tetradecanol, n-1-pentadecanol, n-1-hexadecanol, n-1-heptadecanol  
and n-1-octadecanol. The monohydric alcohols may be unsaturated, as long as they  
do not act as catalyst poisons. Preferable monohydric alcohols are those of formula  
15  $R'OH$  in which  $R'$  is a  $C_2$ - $C_{16}$  alkyl group, most preferably a  $C_4$ - $C_{12}$  alkyl group,  
like 2-ethyl-1-hexanol.

The amount of monohydric alcohol relative to the amount of magnesium compound  
precursor (a) may vary a lot, depending on the quality and quantity of the  
20 magnesium compounds, the dicarboxylic acid dihalide (c), the reactive halogenated  
hydrocarbon (e), is used and on whether the monohydric alcohol  $R'OH$  is used  
alone or in combination with a polyhydric alcohol  $R'(OH)_m$ . The molar ratio  
 $Mg/R'OH$  is preferably between about 1:5 and about 1:1, more preferably between  
about 1:4 and about 1:1, most preferably between about 1:2.5 and about 1:1.5.

25 Typical polyhydric alcohols are ethylene glycol, propene glycol, trimethylene  
glycol, 1,2-butylene glycol, 1,3-butylene glycol, 1,4-butylene glycol, 2,3-butylene  
glycol, 1,5-pentanediol, 1,6-hexanediol, 1,8-octanediol, pinacol, diethylene glycol,  
triethylene glycol, glycerol, trimethylol propane and pentaerythritol. According to  
30 one embodiment of the present invention, the polyhydric alcohol has the formula  
 $R'(OH)_m$ , wherein  $R'$  is a di-, tri- or tetravalent  $C_2$ - $C_{16}$  alkyl group and  $m$  is an  
integer selected from 2, 3, 4, 5 and 6. Preferably,  $R'$  is a divalent or a trivalent  
 $C_2$ -  
 $C_{16}$  alkyl group and  $m$  is an integer selected from 2 and 3. Most preferably the  
polyhydric alcohol is selected from the group consisting of ethylene glycol, 2-butyl-  
35 2-ethyl-1,3-propanediol and glycerol.

In step (i) of the claimed process, it is preferable if at least one polyhydric alcohol  
 $R'(OH)_m$  is used, most preferably together with at least one monohydric alcohol

R'OH. Thereby, the molar ratio  $Mg/R'(OH)_m$  is preferably between about 1:1 and about 1:0.25, most preferably between about 1:0.8 and about 1:0.3.

5 The reaction conditions used in step (i) of the claimed process may vary according to the used reactants and agents. The conditions should be adjusted to give sufficiently of said magnesium compound (ab) between the magnesium compound precursor (a) and the alcohol(s) (b). According to an embodiment of the present invention, said magnesium compound precursor (a) is reacted with said at least one alcohol (b), under at least one of the following conditions:

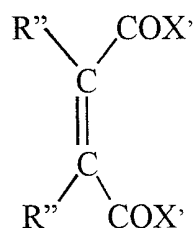
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- at raised temperature, preferably at about 30 °C to about 80 °C,
- for a period of about 10 min to about 90 min, preferably about 30 min,
- in the presence of a C<sub>5</sub>-C<sub>10</sub> hydrocarbon solvent, preferably heptane.

15 In addition to the above embodiments of step (i), other variations and reactions may also be used to produce said magnesium compound (ab), still being within the present scope of protection. Thus, with respect to step (i), the scope of protection should be interpreted under the doctrine of equivalence on the basis of what a skilled person could have done to achieve said intermediate (ab). E.g., the reaction  
20 between a tetra alkoxy silane and a dialkyl magnesium to give a magnesium dialkoxide (see Sumitomo, examples), is within the present scope of protection.

According to the invention, the product of step (i), or a similar composition, i.e. said magnesium compound (ab), is in a succeeding step (ii) reacted with a dicarboxylic  
25 acid dihalide (c) of the formula (1) to give an intermediate (abc), and said intermediate (abc) is in a third step (iii) reacted with a titanium tetrahalide  $TiX''_4$  (d) wherein X'' is a halogen.

30 The formula (1) of the dicarboxylic acid dihalide is:



(1)

wherein each R'' is a similar or different C<sub>1</sub>-C<sub>20</sub> hydrocarbyl group or both R''s form together with the two unsaturated carbons seen in the formula a C<sub>5</sub>-C<sub>20</sub> aliphatic or aromatic ring, and X' is a halogen.

5 Among non-cyclic dicarboxylic acid dihalides, the group consisting of maleic acid dihalide, fumaric acid dihalide and their R'' substituted derivatives such as citraconic acid dihalide and mesaconic acid dihalide, respectively, are the most important. As the invention aims at to converting the dicarboxylic acid dihalides into their corresponding diesters, and the diesters as internal electron donors have to  
10 be coordinable with the magnesium dihalide and the titanium tetrahalide of the catalyst component, the cis-isomeric maleic acid dihalide and its derivatives, such as citraconic acid dihalide, are more advantageous.

However, in order to obtain a catalyst with exceptionally high activity, the R''s of  
15 formula (1) should form together with the two unsaturated carbons of the formula a C<sub>5</sub>-C<sub>20</sub> aliphatic or aromatic ring. Among the cyclic dicarboxylic acid dihalides, the group consisting of phthalic acid dihalide (1,2-benzene dicarboxylic acid dihalide), its hydrogenate 1,2-cyclohexane dicarboxylic acid dihalide, and their derivatives, is the most important. Most preferably, said dicarboxylic acid dihalide (c) is phthaloyl  
20 dichloride.

The amount of the dicarboxylic acid dihalide (c) may vary a lot, depending on the amount of alcohol (b) used in step (i) and the amount of alkoxide present in said magnesium compound (ab) or in said alternative intermediate (abd). It is within the  
25 present scope to adjust the amounts in order to react said intermediates with said dicarboxylic acid dihalide. According to a preferred embodiment of the present invention, in step (ii), said magnesium compound (ab) is reacted with said dicarboxylic acid halide (c) in a molar ratio  $Mg_{\text{total added}}/(c)$  of between 1:1 and 1:0.1, preferably between about 1:0.6 and about 1:0.25.

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The reaction conditions of step (ii) of the claimed process may vary according to the used components and their amounts. However, they should be adjusted to give sufficiently of said reaction product (abc) between said magnesium compound (ab) and said dicarboxylic acid dihalide (c). According to an embodiment of the present  
35 invention, in step (ii), said magnesium compound (ab) is reacted with said dicarboxylic acid dihalide (c), under at least one of the following conditions:

- adding said dicarboxylic acid dihalide (c) under room temperature and heating the obtained reaction mixture,
  - keeping the reactants together at raised temperature, preferably at about 30 °C to about 80 °C,
  - 5 - keeping the reactants together for a period of about 10 min to about 90 min, preferably about 30 min,
  - reacting the reactants in the presence of a C<sub>5</sub>-C<sub>10</sub> hydrocarbon solvent, preferably heptane.
- 10 Usually, a C<sub>5</sub>-C<sub>10</sub> hydrocarbon solvent is used in step (ii). Then, it is preferable, that, after said magnesium compound (ab) has been reacted with said dicarboxylic acid dihalide (c), the C<sub>5</sub>-C<sub>10</sub> hydrocarbon solvent is removed by evaporation, e.g. that heptane is used and removed at about 100 °C to about 110 °C.
- 15 As was said above, it is preferable to add said reactive halogenated hydrocarbon (e) in connection with and preferably after the dicarboxylic acid dihalide (c), i.e. at the end of step (ii). Most preferably, after said C<sub>5</sub>-C<sub>10</sub> hydrocarbon solvent, preferably said heptane, has been removed by evaporation, said intermediate (abc) is contacted with said reactive halogenated hydrocarbon (e). A convenient contacting period is
- 20 about 10 min to about 90 min, preferably about 30 min.

In this reaction sequence (i)→(ii)→(iii), after said intermediate (abc) has been contacted with said reactive halogenated hydrocarbon (e), preferably in step (ii), a dissolving C<sub>5</sub>-C<sub>10</sub> hydrocarbon, such as toluene, is preferably added. Without

25 limiting the scope of patent protection, the hydrocarbon is believed to dissolve the reaction product and/or to lower the viscosity of its solution, thus making the intermediate (abc, including (e)) more available for reaction with the titanium tetrahalide TiX''<sub>4</sub> (d) in the succeeding step (iii). Most preferably, a molar ratio

Mg<sub>total added</sub>/toluene of between about 1:2 and about 1:10 is used in the addition.

30

In step (iii), the magnesium compound precursor/alcohol/dicarboxylic acid dihalide reaction product (abc) is reacted with at least one titanium tetrahalide TiX''<sub>4</sub> (d), wherein X'' is a halogen. Equivalent with said titanium tetrahalide is the combination of an alkoxy titanium halide and a halogenation agent thereof, which

35 are able to form a titanium tetrahalide in situ. However, the most preferred titanium tetrahalide (d) is titanium tetrachloride.

The amount of titanium tetrahalide (d) may vary a lot and depends e.g. on the manner of contacting it with said intermediate (abc). If the titanium tetrahalide is added to the intermediate or magnesium compound, a large stoichiometric excess thereof is not needed. Within the scope of the claimed process, the amount of titanium tetrahalide may be optimized to give a suitable catalyst. Most preferably, in  
5 titanium tetrahalide (d) in a molar ratio  $Mg_{\text{total added}}/(d)$  of between 1:100 and 1:1, preferably between about 1:50 and about 1:5, most preferably about 1:10.

10 In the reaction sequence (i)→(iii), it is preferable if in step (iii), said intermediate (abc), more preferably a solution thereof, is added slowly, most preferably dropwise, to said titanium tetrahalide (d) to form a solution of said catalyst component. Thereby, the titanium tetrahalide is preferably hot, most preferably at 110 °C. The best results are obtained, if in step (iii), a toluene solution of said  
15 intermediate (abc) is added dropwise to said titanium tetrahalide (d) at 110 °C. The preferred reaction time is about 5 min to about 20 min, most preferably about 10 min.

After the reaction sequence (i)→(ii)→(iii), the reaction product, which is a  
20 precursor of, or a crude version of said catalyst component, is recovered in a recovery step (iv). Preferably, said catalyst component is recovered by continuously heating a solution of said catalyst component, most preferably said toluene solution of said catalyst component, for the precipitation of the catalyst component in crude form or a precursor thereof and allowing it to settle. Immediately before said  
25 precipitation, preferably a C<sub>5</sub>-C<sub>10</sub> hydrocarbon solvent, more preferably toluene, most preferably toluene in a molar ratio  $Mg_{\text{total added}}/\text{toluene}$  of about 1:10 to about 1:100, is added to the catalyst component solution. After the crude catalyst component or the precursor has settled, the supernatant liquid is removed e.g. by decanting or siphoning.

30 After the recovery step (iv), said catalyst component in crude form or said precursor is optionally washed in a washing step (v). By precursor is meant a reaction product, which still is not in the form of the final catalyst component. This state of things derives from the nature of the reaction product, which may be a larger  
35 complex (see definition above) consisting of or containing one or several molecules and/or smaller complexes. Because of the loose structure of such a larger complex or complex mixture, washing will remove some of the complexes and/or molecules and essentially change the composition of the remaining solid product.

It is preferable if, in step (v), said recovered crude catalyst component or its precursor is washed with toluene, preferably with hot (e.g. 90 °C) toluene. It is also preferable, if in step (v), said recovered crude catalyst component, said recovered catalyst component precursor or said preliminary washed catalyst component is washed with heptane, most preferably with hot (e.g. 90 °C) heptane. Further, it is preferable, if in step (v), said recovered crude catalyst component, said recovered catalyst component precursor or said preliminary washed catalyst component is washed with pentane. A washing step (v) typically includes several substeps which gradually increase the magnesium dihalide content of the catalyst precursor. Such a washing sequence is, for example, one wash with toluene at 90 °C, two washes with heptane at 90 °C and one wash with pentane at room temperature.

The washing can according to the invention be optimized to give a catalyst with novel and desirable properties. Thus in step (v), said recovered catalyst component is preferably washed to give the following ratio of said magnesium dihalide, said titanium tetrahalide, and said dicarboxylic acid ester as internal electron donor ED (3):



wherein  $\text{MgX}_2$  is said magnesium dihalide,  $\text{TiX}'_4$  is said titanium tetrahalide and ED is said dicarboxylic acid ester as internal electron donor, preferably a phthalic acid diester. X and  $\text{X}'$  are both preferably Cl.

Finally, the washed catalyst component is usually dried, preferably by evaporation.

In appendices 1 and 2 are described the schemes of four embodiments of the present invention; two starting from a magnesium dihalide  $\text{MgX}_2$  and two starting from a dialkyl magnesium  $\text{R}_2\text{Mg}$ .

In addition to the above described process, the invention also relates to an olefin polymerization catalyst component comprising a magnesium dihalide, a titanium tetrahalide, and a dicarboxylic acid diester as internal electron donor ED, which has been prepared according to the above described process. By said catalyst component is meant the so called procatalyst component, i.e. the transition metal component of the whole olefin catalyst system, which system additionally includes a so called cocatalyst, i.e. an organic compound of a non-transition metal, and optionally a so called external electron donor.

An advantageous embodiment of the catalyst component according to the invention comprises a magnesium dihalide, a titanium tetrahalide, and a dicarboxyl acid ester as internal electron donor ED, is essentially homogenous and has the following ratio of said magnesium dihalide, said titanium tetrahalide, and said dicarboxylic acid ester as internal electron donor ED (3):



wherein  $MgX_2$  is said magnesium dihalide,  $TiX_4$  is said titanium tetrahalide and ED is said dicarboxylic acid ester as internal electron donor, preferably a phthalic acid diester. Preferably  $X = X'' = Cl$ . Most preferably, the catalyst component is a complex having the formula (3). This composition gives the highest activity, and when using in its preparation a polyol  $R'(OH)_m$ , wherein  $R'$  is an m-valent  $C_1-C_{20}$  hydrocarbyl group and m is an integer selected from 2, 3, 4, 5 and 6, its morphology can conveniently be adjusted to give olefin polymers of various desired particle sizes and particle size distributions (PSD).

When adding during the preparation process of the claimed catalyst component a reactive halogenated hydrocarbon (e) of the formula (2)



wherein  $R'''$  is an n-valent  $C_1-C_{20}$  hydrocarbyl group,  $X'''$  is a halogen and n is an integer selected from 1, 2, 3 and 4, the product will preferably contain more halogen than was to be expected on the basis of the  $MgX_2$  and  $TiX_4$  present. Preferably, the claimed catalyst component might contain halogen from about 10% to about 60% more than the amount of halogen calculated on the basis of the amounts of magnesium and titanium present, assuming that all of the magnesium is in the form of said  $MgX_2$  and essentially all of the titanium is in the form of said  $TiX_4$ .

In the claimed catalyst component, the magnesium halide ( $X = Cl$ ) structure has an X-ray diffraction pattern which differs from the X-ray diffraction pattern of pure  $MgCl_2$ . It preferably shows an X-ray diffraction pattern with a lamellar thickness indicating peak at  $17^\circ 2\Theta$ , showing a clear position shift compared to normal amorphous  $MgCl_2$  which gives a height indicating peak at  $15^\circ 2\Theta$ . Indeed, according to J. Dorrepaal et al. (J. Appl. Crystallography, 1984 17, page 483), the crystal structure of  $MgCl_2$  is characterized by  $a=3,640 \text{ \AA}$  and  $C=17,673 \text{ \AA}$ . In an X-ray diffraction pattern the peak at about  $15^\circ 2\Theta$  is in the direction (003) of the c-

axis, i.e. describing the height to the hexagonal unit cell, when Cu K $\alpha$  radiation is used.

In addition to the above described process and catalyst component, the invention also relates to a process for the polymerization of olefins. The process is characterized by the steps of

- (A) preparing a catalyst component according to the above defined process,
- 10 (B) feeding to at least one polymerization reactor said catalyst component, as well as a cocatalyst, which has the formula (4)



15 wherein R is a C<sub>1</sub>-C<sub>10</sub> alkyl, preferably a C<sub>1</sub>-C<sub>4</sub> alkyl, most preferably ethyl, X is a halogen, preferably chlorine, p is an integer from 1 to (3r-1), preferably 2 or 3, most preferably 3, and r is 1 or 2, preferably 1, the molar ratio between said catalyst component and said cocatalyst, expressed as Al/Ti, preferably being 10-2000, more preferably 50-1000, most preferably 200-500,

20 optionally an external electron donor, which preferably is a silane, more preferably a C<sub>1</sub>-C<sub>12</sub> alkyl - C<sub>1</sub>-C<sub>12</sub> alkoxy silane, most preferably cyclohexyl methyl dimethoxy silane,

25 optionally a C<sub>4</sub>-C<sub>10</sub> hydrocarbon solvent, preferably pentane, hexane and/or heptane,

preferably a chain transfer agent, which is hydrogen, and

30 at least one olefin monomer, which preferably is propene,

(C) carrying out the polymerization of said olefin monomer in said at least one polymerization reactor to give an olefin polymer (=homopolymer or copolymer) and

35 (D) recovering said olefin polymer.

In the claimed olefin polymerization process, the used (transition metal) catalyst component can be prepared according to any above described embodiment of the catalyst component preparation process.

5 According to one further embodiment of the invention, olefins are polymerized by the steps of

(A) providing a solid olefin polymerization catalyst component which is essentially homogenous and comprises a magnesium dihalide, a titanium tetrahalide, and a  
10 dicarboxylic acid diester as internal electron donor ED in the following ratio (3):



wherein  $MgX_2$  is said magnesium dihalide,  $TiX''_4$  is said titanium tetrahalide, X  
15 and/or  $X''$  is preferably Cl, and ED is said dicarboxylic acid diester as internal donor, preferably a phthalic acid diester,

(B) feeding to at least one polymerization reactor said catalyst component, as well  
20 as a cocatalyst which has the formula (4)



wherein R is a  $C_1-C_{10}$  alkyl, preferably a  $C_1-C_4$  alkyl, most preferably ethyl, X is a  
25 halogen, preferably chlorine, p is an integer from 1 to  $(3r-1)$ , preferably 2 or 3, most preferably 3, and r is 1 or 2, preferably 1, the molar ratio between said catalyst component and said cocatalyst, expressed as Al/Ti, preferably being 10-2000, more preferably 50-1000, most preferably 200-500,

optionally an external electron donor, which preferably is a silane, more preferably  
30 a  $C_1-C_{12}$  alkyl -  $C_1-C_{12}$  alkoxy silane, most preferably cyclohexyl methyl dimethoxy silane,

optionally a  $C_4-C_{10}$  hydrocarbon solvent, preferably pentane, hexane and/or  
35 heptane,

preferably a chain transfer agent, which is hydrogen, and

at least one olefin monomer, which preferably is propylene,

(C) carrying out the polymerization of said olefin monomer in said polymerization reactor to give an olefin polymer (= homopolymer or copolymer) and

(D) recovering said olefin polymer.

5

The invention is described below by means of examples, the purpose of which merely is to illustrate the invention.

### Examples

10

The following figures illustrate the examples:

15

Figure 1 shows an example of a regular amorphous  $MgCl_2$  X-ray diffraction pattern of a polymer prepared by using a catalyst according to the invention.

20

Figure 2 shows the IR spectrum of a catalyst.

Figure 3 shows the activity of the PDC catalysts as a function of their Mg/Ti molar ratio.

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Figure 4 shows a simplification of the washing procedure in the examples when going from example 6 to examples 7, 8 and 9.

Figure 5 shows the X-ray diffraction pattern of the catalyst of example 7.

Figure 6 shows the IR spectrum of the catalyst prepared in example 6.

30

Figure 7 shows the particle size distribution (PSD) of a propene polymer that was obtained when using the catalyst of example 7 in a test polymerization.

Figure 8 shows the Ti % in some catalyst according to the invention.

35

Figure 9 shows the per cent of polymer (= di, oligo or polyester), calculated as  $100\% - \% \text{ known species}$ , correlated to the number of -OH groups in the added alcohol.

- Figure 10 shows the molar proportions of Ti:Mg:Donor in the catalysts.
- Figure 11 shows the activity in bulk polymerization of the catalysts in kg PP/g cat units.
- 5 Figure 12a shows the particle size distribution (PSD) setup for the polymer obtained with the catalyst of example 9.
- 10 Figure 12b shows the particle size distribution (PSD) setup for the polymer obtained with the catalyst of example 10.
- Figure 12c shows the particle size distribution (PSD) setup for the polymer obtained with the catalyst of example 11.
- 15 Figure 12d shows the particle size distribution (PSD) setup for the polymer obtained with the catalyst of example 12.
- Figure 12e shows the particle size distribution (PSD) setup for the polymer obtained with the catalyst of example 13.
- 20 Figure 13 shows an X-ray diffraction pattern of a catalyst according to the invention.

The following chemicals, chemical characterization of the catalyst components, bulk polymerisation conditions and characterization of the polymers were used in all examples.

#### Chemicals used in the examples

- 30 The magnesium alkyl ( $MgR_2$ ) used was BOMAG-A® from Schering which was a 20% heptane solution of butyloctylmagnesium ( $(n-C_4H_9)_{1.5}(n-C_8H_{17})_{0.5}Mg$ ) with a magnesium content of 2.92% and a density of  $\zeta = 0.729$  g/ml. Dry 2-ethyl-1-hexanol (EHA) (>99%) was used as a monohydric alcohol. 2-butyl-2-ethyl-1,3-propanediol (BEPD) was used as a first dihydric alcohol (99%). Ethylene glycol (EG) was used as a second dihydric alcohol. Glycerol (GLY) was used as a trihydric alcohol. 1,2-phthaloyldichloride (PDC) (>95%) was dried and used as chlorination agent. 1-chlorobutane (butylchloride) (BuCl) from Fluka (19750) was dried and used as a reactive halogenated hydrocarbon. Titanium tetrachloride was
- 35

used as such as a titanation agent ( $\text{TiCl}_4$ ). Further, toluene, heptane ( $\text{C}_7$ ), pentane ( $\text{C}_5$ ), nitrogen gas ( $\text{N}_2$ ) and silicon oil 200/5 were used.

5 A 100% solution of triethylaluminium (TEA) was used as cocatalysts in the bulk polymerizations. Cyclohexyl methyl dimethoxy silane (CMDS) was used as external donor in the polymerizations.

### Chemical characterization of the catalyst components

10 The catalyst components were characterized with respect to their chemical composition by measuring their Mg, Ti and Cl content. The Mg and Ti analysis was started by dissolving the samples in a mixture of nitric and hydrofluoric acid. The metal was measured by flame atomic absorption with a nitrous oxide/acetylene flame. Chloride was determined after dissolution in diluted sulphuric acid by  
15 potentiometric titration with a standard silver nitrate solution.

The determination of the phthalic esters (diethylphthalate DEP and dioctylphthalate DOP) and the phthalic anhydride (PA) were done by first dissolving the sample in acetone. The samples were filtered and run by solution chromatography (HPLC).  
20 Each component was identified by comparing the respective retention time and ultra violet (UV) spectra with standard components.

To check the conversion rate of the ethanol (EtOH), 2-ethyl-hexanol (EHA), or other alcohol added in the synthesis, the alcohol content of the catalysts were  
25 measured by gas chromatography (GC). A Hewlett Packard 5890 GC with a 60 m DB-1 column was used for the GC analyses. The column had an diameter of 0.25 mm with a film thickness of 1  $\mu\text{m}$ . An FID detector was used.

The WAXS X-ray diffraction patterns were collected in reflection mode between  
30  $2\theta$  and  $70^\circ$  with a Siemens D500 instrument. The  $\text{CuK}_\alpha$  radiation wavelength was 1.54  $\text{\AA}$ .

The IR spectra were taken by a Nicolet 510 FTIR equipment with  $2\text{ cm}^{-1}$  resolution.

### 35 Bulk polymerization of propene

Propene was polymerized in a stirred tank reactor having a volume of 5 l. TEA as a cocatalyst, CMDS as an external donor and 30 ml of n-pentane were mixed and

allowed to react for 5 minutes. Half of the mixture was added to the polymerization reactor and the other half was mixed with said catalyst component. After additional 5 minutes the catalyst/TEA/CMDS/n-pentane mixture was introduced into the reactor. The Al/Ti mole ratio was 250 and the Al/CMDS mol ratio was 10 mol/mol. 70 mmol hydrogen and 1400 g of propene were introduced into the reactor and the temperature was raised within 15-30 minutes to 70 °C. The polymerization time was 60 minutes.

### Characterization of the polymers

10

The polymers were characterized with respect to their melt flow rate (MFR<sub>2</sub>), bulk density (BD) and the fraction of total solubles in xylene (XS). MFR (g/10 min) was measured using the standard ISO 1133 (2.16 kg load, 230 °C). The bulk density (in kg/m<sup>3</sup>) of the material was measured from a 100 ml cylinder. The amount of total xylene solubles (in wt-%) was measured by dissolving a polymer sample in 250 ml of boiling xylene, precipitating the isotactic material at 25 °C and evaporating the solvent from the soluble sample fraction.

15

### Examples 1 to 4

20

The setup of the examples is listed in Table 1.

**Table 1** The experimental setup for examples 1-4

| Example | MgR <sub>2</sub> /ROH | Diol | BuCl | Mg/Ti | Mg/PDC |
|---------|-----------------------|------|------|-------|--------|
| 1       | 1:2                   | No   | No   | 1:10  | 1:1    |
| 2       | 1:2                   | Yes  | Yes  | 1:10  | 1:0,5  |
| 3       | 1:3                   | No   | Yes  | 1:2   | 1:0,5  |
| 4       | 1:3                   | Yes  | Yes  | 1:10  | 1:0,5  |

25

In example 1, no butyl chloride was used. In examples 1 and 3, no diol was used. The synthesis was started by introducing 35 mmol of MgR<sub>2</sub> (BOMAG-A®) into a 100 ml glass reactor at room temperature. The molar ratio MgR<sub>2</sub>/C<sub>7</sub> in this solution was 1:7.

30

In the next step EHA was added in a molar ratio MgR<sub>2</sub>/EHA of 1:2 or 1:3 depending on the experimental setup. After the addition of EHA, the temperature was increased to 60 °C and the reactants were allowed to react with each other for

30 min. After this the reaction solution was cooled down to room temperature. Depending of the experimental setup, the second alcohol, i.e. BEPD was introduced into the reactor. The  $MgR_2/BEPD$  molar ratio was 1:0.5. Again, the temperature was increased to 60 °C and the reactants were allowed to react with each other at this temperature for 30 min after which the temperature was lowered to room temperature.

The next reagent to be added was the ortho-phthaloyl dichloride (PDC). This chlorination agent was added in a  $Mg/PDC$  molar ratio of 1:1 or 1:0.5 according to Table 1. The temperature was increased to 60 °C and the reaction solution was kept at this temperature for 30 min. After this the temperature of the reaction solution was lowered to room temperature. Depending on the experimental setup the second chlorination agent, butylchloride (BuCl) was now added at a  $Mg/BuCl$  molar ratio of 1:1. Again the temperature was increased to 60 °C and the reaction solution was kept at this temperature for 30 min.

In examples 2 and 3 silicon oil was added as particle size modifier. It was introduced directly onto the hot solution. The molar ratio of the added silicon oil to magnesium was 5:1, calculated as mol silice per mol magnesium (Si/Mg).

A portion of toluene was added either to the hot Mg solution (examples 1 and 4) or to the receiving  $TiCl_4$  solution (examples 2 and 3) to increase the solubility of the components. The  $C_6H_5CH_3/Mg$  molar ratio was 5:1.

While the Mg-solution was being prepared, a portion of  $TiCl_4$  was introduced into a 250 ml thermostated glass reactor. The  $TiCl_4/Mg$  molar ratio was 2:1 or 10:1. A portion of  $TiCl_3OEt$  was added to the  $TiCl_4$  solution in examples 1, 2 and 3. The  $TiCl_3OEt/Mg$  molar ratio was 3:1. The temperature of this receiving solution was increased to 110 °C.

The Mg-solution was then added dropwise to this hot  $TiCl_4$  solution. The whole addition took 20 min. After this the reactants were allowed to react with each other for 5 min (examples 2 and 4) or 1 h (examples 1 and 3).

After the components had reacted with each other, the reaction solution was allowed to cool down to 90 °C, after which 40 mol heptane ( $C_7$ ) was added to precipitate the catalyst complex. After this the supernatant liquid was siphoned off.

The catalyst component was washed with toluene or a mixture of toluene and  $\text{TiCl}_4$ . The toluene wash was carried out at 90 °C for 20 min, under stirring. Then the catalyst component was washed two times at 90 °C for 10 min with heptane. The  $\text{C}_7/\text{Mg}$  molar ratio in these washes was 40:1. Thereafter, the catalyst component was washed with pentane ( $\text{C}_5$ ) for 10 min at room temperature. The  $\text{C}_5/\text{Mg}$  molar ratio was 50:1. Finally, the catalyst component was dried under a stream of nitrogen.

All the catalyst were characterized chemically according to the description above and they were test polymerized as described above. All the results are listed in Table 2, in which examples 4a and 4b are parallel examples and EtOH stands for ethanol.

**Table 2**

| Catalyst                      | Example 1 | Example 2 | Example 3 | Example 4a | Example 4b |
|-------------------------------|-----------|-----------|-----------|------------|------------|
| Mg (wt-%)                     | 8.0       | 14.1      | 16.4      | 11.9       | 11.9       |
| Mg (mol/100 g catalyst)       | 0.33      | 0.58      | 0.68      | 0.49       | 0.49       |
| Ti (wt-%)                     | 5.8       | 1.8       | 2.5       | 3.1        | 3.1        |
| Ti (mol/100 g catalyst)       | 0.12      | 0.04      | 0.05      | 0.07       | 0.07       |
| BEPD (wt-%)                   |           | 0.27      |           | 0.48       | 0.48       |
| BEPD (mol/100 g catalyst)     |           | 0.002     |           | 0.003      | 0.003      |
| EHA (wt-%)                    |           | 0.21      | 0.001     | 0.13       | 0.13       |
| EHA (mol/100 g catalyst)      |           | 0.002     | 0.001     | 0.001      | 0.001      |
| EtOH (wt-%)                   |           | 0.76      | 0.27      |            |            |
| DEP (wt-%)                    | 8.54      | 1.42      | 1.27      |            |            |
| DEP (mol/100 g catalyst)      | 0.038     | 0.006     | 0.006     |            |            |
| DOP (wt-%)                    | 28.4      | 16.8      | 11.1      | 33.6       | 33.6       |
| DOP (mol/100 g catalyst)      | 0.073     | 0.043     | 0.028     | 0.086      | 0.086      |
| PA (wt-%)                     | 1.46      | 0.09      |           | 0.9        | 0.9        |
| Mg (molar ratio)              | 2.7       | 15.4      | 12.9      | 7.6        | 7.6        |
| Ti (molar ratio)              | 1         | 1         | 1         | 1          | 1          |
| Donor (molar ratio)           | 0.9       | 1.3       | 0.7       | 1.3        | 1.3        |
| Toluene (wt-%)                |           | 0.71      | 0.22      | 0.07       | 0.07       |
| $\text{C}_5$ (wt-%)           |           | 1.02      | 0.46      | 0.37       | 0.37       |
| $\text{C}_7$ (wt-%)           |           | 2.15      | 1.18      | 0.70       | 0.70       |
| Activ. (kg PP/g cat)          | 4.8       | 7.00      | 10.6      | 26.6       | 26.1       |
| Activ. (kg PP/g Ti)           | 83        | 389       | 424       | 858        | 842        |
| BD ( $\text{kg}/\text{m}^3$ ) | 400       | 350       | 450       | 430        | 470        |
| $\text{MFR}_2$ (g/10 min)     | 10.3      | 8.3       | 10.4      | 6.2        | 6.7        |
| XS (wt-%)                     | 2.4       | 1.7       | 1.6       |            | 1.8        |

The results of the catalyst synthesis show that:

1. BuCl greatly effects the Mg/Ti molar ratio.
2. There is an oligo- or polyester formation if a diol and a phthaloyl dichloride is  
5 used in the synthesis of the donor compound.
3. The presence of DOP in the precipitating  $(\text{MgCl}_2)_x\text{TiCl}_4\text{DOP}$  complex favours the outcome of regular amorphous crystal structure of the complex  $\text{MgCl}_2$ .
4. Ethers are present in the  $(\text{MgCl}_2)_x\text{TiCl}_4\text{DOP}$  catalyst complex.
5. BuCl greatly improves the catalyst activity.
- 10 6. Optimum composition of the catalyst complex is  $(\text{MgCl}_2)_x\text{TiCl}_4\text{DOP}$ , wherein X is from about 7 to about 10.
7. Activities of up to 27 kg PP/g cat are reached.

Most of the catalysts originating from a synthesis where PDC had been used  
15 showed a quite regular amorphous  $\text{MgCl}_2$  X-ray diffraction pattern. As an example of these patterns, the pattern of example 2 is shown in Figure 1. The  $2\theta$ -value is given in abscisse. Only one of the catalysts belonging to this latter group showed a strongly disturbed X-ray pattern, while the rest of them followed nicely the above mentioned features. However one pattern (in Figure 13) showed an unusual halo  
20 between  $18^\circ$  and  $22^\circ 2\theta$  reflecting the haloformation significant for  $\text{MgCl}_2(\text{Mg}(\text{OR})_2)_2$  complexes.

In all the IR spectra from the catalysts prepared out of PDC there were clear peaks indicating the presence of ether at  $1080\text{ cm}^{-1}$ . In all these spectra there were also  
25 clear peaks at  $1860$  and  $1760\text{ cm}^{-1}$  indicating the presence of an acid anhydride. An example of these spectra is shown in Figure 2 where the IR spectrum of the catalyst component of example 4 is shown. The wavenumber is shown in abscisse and the % of transmittance in ordinate. (1) peale indicates ether and (2) peak indicates acid anhydride.

30

It is believed that BuCl reduces the  $\text{TiCl}_4$  content relative to the  $\text{MgCl}_2$  content of the catalyst component. This can be seen in Figure 3 where the activities (in  
orelinate) of the PDC catalysts are shown as a function of their Mg/Ti molar ratio (in abscisse). Here it can be seen that the three catalysts that has been chlorinated by  
35 BuCl are forming an own group in the right upper corner of the figure, while the catalysts that have not been contacted with BuCl are forming a group in the lower left corner of the figure. The graph indicates that there is an optimum activity corresponding to an Mg/Ti molar ratio of 7-10. This finding is supported by an

another result from examples 1-4 indicating that a moderate washing of the catalyst is optimum.

### Examples 5 to 8

5

The experimental setups for examples 5-8 are listed in Tables 3-6. Example 4b was done for comparison. The chemicals used were identical to those used in examples 1-4, as well as the characterisation methods. The catalysts were polymerized according to the polymerization process described above.

10

In example 5 the amount of BuCl is increased to the double compared to example 4b. Example 6 was identical to example 5, but no heptane was added to the TiCl<sub>4</sub> solution. The principle of the catalyst washing in example 6 is shown in Figure 4 left column.

15

Example 7 was identical to example 6, but a larger part of the monoalcohol was replaced by the diol. Example 8 was a repetition of the third (example 7) with the exception that the mono and dihydric alcohols were mixed together and added to the catalyst synthesis in a joined addition step. The principle of the catalyst washing is in examples 7-9 is shown in Figure 4, right column.

20

### Preparation of the catalyst components

In the following, example 6 is described. The other examples were performed in a similar way. Into a 250 ml glass reactor was introduced 40 ml of a 20% heptane solution of BOMAG-A® (35.01 mmol). Onto this was added 11.0 ml (70.01 mmol) of EHA. The temperature of the reaction solution was increased to 60 °C and the reactants were allowed to react with each other for 30 min. Then, 2.805 g (17.50 mmol) of BEPD was first heated with 2 ml of heptane in a septum bottle to 40 °C to obtain a feed solution. This solution was siphoned to the main reactor. To secure complete transfer, the septum bottle was rinsed with another portion of 1.5 ml of heptane that was also siphoned to the main reactor. Again the reactants were allowed to react for 30 min. 2.52 ml (3.554 g, 17.50 mmol) of PDC was introduced and allowed to react for 30 min. The last reagent when preparing the Mg complex solution was 4.000 ml (76.570 mmol) of BuCl that also was allowed to react for 30 min. 20 ml (187.8 mmol) of toluene was added as last step in the preparation of the Mg complex solution in order to decrease its viscosity.

35

The following step in the catalyst synthesis was the addition of the Mg complex into 38.48 ml (350.1 mmol) of  $\text{TiCl}_4$ . The addition was done dropwise, the  $\text{TiCl}_4$  solution having a temperature of 110 °C. The catalyst was allowed to be formed in this solution for 5 min after which the  $\text{TiCl}_4$  solution was allowed to cool down to 90 °C after which 110 ml of heptane was added (in examples 5 and 6) to improve the precipitation of the catalyst. The reaction solution was kept at 90 °C for 20 min after which the catalyst was allowed to settle and the liquid was siphoned off. After this, the catalyst was washed twice with a 130 ml portion of a 10%  $\text{TiCl}_4$  toluene solution at 90 °C for 30 min. Finally the catalyst was washed twice with 180 ml portions of heptane also at 90 °C for 30 min and lastly with a 150 ml portion of pentane at room temperature for 15 min. The catalyst was dried from hydrocarbons under a stream of nitrogen.

In Tables 3-6, mol.ratio stands for molar ratio, stirr. stands for stirring time in minutes, settl. stands for settling time in minutes and 22→60 means that the temperature was risen from 20 to 60 °C. No stirring was used during the drying.

Table 3

| Example 5                       | mol.ratio       | mmol            | ml   | °C    |
|---------------------------------|-----------------|-----------------|------|-------|
| BOMAG-A® (20%/C7)               | 1               | 35.01           | 40.0 |       |
| EHA                             | 2               | 70.01           | 11.0 |       |
| BEPD                            | 0.5             | 17.50           |      |       |
| PDC                             | 0.5             | 17.50           | 2.5  |       |
| BuCl                            | 2.2             | 76.57           | 8.0  |       |
| Toluene                         |                 |                 | 20.0 |       |
| $\text{TiCl}_4$ (110°C)         | 10              | 350.1           | 38.5 |       |
| Precipitation in C <sub>7</sub> | 20              | 5               |      | 90    |
| Washings:                       | stirr.<br>(min) | settl.<br>(min) | ml   | °C    |
| Toluene (+10% $\text{TiCl}_4$ ) | 30              | 5               |      | 90    |
| C7                              | 26              | 2               |      | 90    |
| C7                              | 28              | 2               |      | 90    |
| C5                              | 19              | 2               |      | 90    |
| Drying (N <sub>2</sub> ) 46 min |                 |                 |      | 22→60 |

Table 4

| <b>Example 6</b>                  | <b>mol.ratio</b> | <b>mmol</b>   | <b>ml</b> |           |
|-----------------------------------|------------------|---------------|-----------|-----------|
| BOMAG-A® (20%/C7)                 | 1                | 35.01         | 40.0      |           |
| EHA                               | 2                | 70.01         | 11.0      |           |
| BEPD                              | 0.5              | 17.50         |           |           |
| PDC                               | 0.5              | 17.50         | 2.5       |           |
| BuCl                              | 2.2              | 76.57         | 8.0       |           |
| Toluene                           |                  |               | 20.0      |           |
| TiCl <sub>4</sub> (110°C)         | 10               | 350.1         | 38.5      |           |
| <b>Washings:</b>                  | <b>stirr.</b>    | <b>settl.</b> | <b>ml</b> | <b>°C</b> |
|                                   | <b>(min)</b>     | <b>(min)</b>  |           |           |
| Toluene (+10% TiCl <sub>4</sub> ) | 30               | 4             |           | 90        |
| C7                                | 36               | 3             |           | 90        |
| C7                                | 32               | 6             |           | 90        |
| C5                                | 30               | 2             |           | 90        |
| Drying (N <sub>2</sub> ) 45 min   |                  |               |           | 22→60     |

Table 5

5

| <b>Example 7</b>                  | <b>mol.ratio</b> | <b>mmol</b>   | <b>ml</b> |           |
|-----------------------------------|------------------|---------------|-----------|-----------|
| BOMAG-A® (20%/C7)                 | 1                | 35.01         | 40.0      |           |
| EHA                               | 1.5              | 52.51         | 8.3       |           |
| BEPD                              | 0.75             | 26.25         |           |           |
| PDC                               | 0,4              | 14,00         | 2,0       |           |
| BuCl                              | 2,2              | 76,57         | 8,0       |           |
| Toluene                           |                  |               | 20,0      |           |
| TiCl <sub>4</sub> (110°C)         | 10               | 350,1         | 38,5      |           |
| <b>Washings:</b>                  | <b>stirr.</b>    | <b>settl.</b> | <b>ml</b> | <b>°C</b> |
|                                   | <b>(min)</b>     | <b>(min)</b>  |           |           |
| Toluene (+10% TiCl <sub>4</sub> ) | 36               | 5             | 130       | 90        |
| C7                                | 30               | 3             | 150       | 90        |
| C7                                | 30               | 3             | 145       | 90        |
| C5                                | 30               | 3             | 150       | 90        |
| Drying (N <sub>2</sub> ) 45 min   |                  |               |           | 22→60     |

Table 6

| Example 8                         | mol.ratio       | mmol            | ml    |       |
|-----------------------------------|-----------------|-----------------|-------|-------|
| BOMAG-A® (20%/C7)                 | 1               | 35.01           | 40.0  |       |
| EHA                               | 1.5             | 52.51           | 8.3   |       |
| BEPD                              | 0.75            | 26.25           |       |       |
| PDC                               | 0,4             | 14,00           | 2,0   |       |
| BuCl                              | 2,2             | 76,57           | 8,0   |       |
| Toluene                           |                 |                 | 20,0  |       |
| TiCl <sub>4</sub> (110°C)         | 10              | 350,1           | 38,48 |       |
| <hr/>                             |                 |                 |       |       |
| Washings:                         | stirr.<br>(min) | settl.<br>(min) | ml    | °C    |
| Toluene (+10% TiCl <sub>4</sub> ) | 44              |                 | 140   | 90    |
| C7                                | 25              | 27              | 150   | 90    |
| C7                                | 30              | 7               | 150   | 90    |
| C5                                | 30              | 9               | 155   | 90    |
| Drying (N <sub>2</sub> ) 37 min   |                 |                 |       | 22→60 |

The catalysts and the polymers obtained were analyzed and characterized as described above for examples 1-4. The results are listed in Table 7.

Table 7

| Catalyst                    | Example 4b | Example 5 | Example 6 | Example 7 | Example 8 |
|-----------------------------|------------|-----------|-----------|-----------|-----------|
| Mg (wt-%)                   | 11.5       | 8.8       | 13.4      | 13.4      | 12.6      |
| Mg (mol/100g catalyst)      | 0.473      | 0.362     | 0.551     | 0.551     | 0.519     |
| Ti (wt-%)                   | 2.9        | 4.5       | 2.1       | 3.2       | 2.4       |
| Ti (mol/100g catalyst )     | 0.061      | 0.094     | 0.044     | 0.067     | 0.050     |
| BEPD (wt-%)                 | 0.01       | 0.96      | 0.65      | 1.66      | 1.24      |
| BEPD (mol/100g catalyst )   | 0.000      | 0.006     | 0.004     | 0.010     | 0.008     |
| EHA (wt-%)                  | 0.24       | 0.45      | 0.44      | 0.33      | 0.33      |
| EHA (mol/100g catalyst )    | 0.0018     | 0.0035    | 0.0034    | 0.0025    | 0.0025    |
| DOP (wt-%)                  | 35.5       | 41.8      | 34.7      | 21.9      | 21.1      |
| DOP (mol/100g catalyst )    | 0.091      | 0.107     | 0.089     | 0.056     | 0.054     |
| PA (wt-%)                   | 1.0        | 0.8       | 1.7       | 1.2       | 1.0       |
| Mg (mol Mg/mol Ti)          | 7.8        | 3.9       | 12.6      | 8.3       | 10.3      |
| Donor (mol Donor/mol Ti)    | 1.5        | 1.1       | 2.0       | 0.8       | 1.1       |
| Toluene (wt-%)              | 0.09       | 0.17      | 0.04      | 0.32      | 0.37      |
| C5 (wt-%)                   | 0.6        | 0.17      | 0.06      | 0.39      | 0.45      |
| C7 (wt-%)                   | 0.15       | 0.40      | 0.15      | 1.90      | 8.73      |
| Volatil. tot. (wt-%)        | 0.84       | 0.74      | 0.25      | 2.61      | 9.55      |
| Activ. (kg PP/g cat)        | 19.4       | 15.2      | 12.0      | 21.2      | 19.1      |
| Activ. (kg PP/g Ti)         | 669        | 339       | 569       | 472       | 795       |
| BD (kg/m <sup>3</sup> )     | 470        | 400       | 290       | 310       | 300       |
| MFR <sub>2</sub> (g/10 min) | 6.5        | 7.2       | 10.5      | 8.0       | 8.9       |
| XS (wt-%)                   |            |           | 3.2       | 2.3       | 3.1       |

The examples 5 to 8 show that very good morphology of the polymer material can be achieved if the heptane precipitation of the catalyst is left out from the catalyst synthesis. 65% of the polymer particles had a particle size between 0.5 and 1.0 mm. The catalyst yield in the catalyst synthesis was the same even if heptane precipitation was not used.

Increased amount of oligo or polyester ingredients added to the catalyst synthesis increased the amount of organic material in the catalyst from 2 to 10%.

X-ray diffraction patterns were taken from all catalysts. The characteristic features are a quite sharp peak at 50° 2 $\Theta$  describing the broadness of the crystal plates and, a halo formation between 30° and 35° 2 $\Theta$  describing the intermediate reflecting

layers. There was however, a clear difference. In crystalline  $\text{MgCl}_2$  there is an intensive peak at  $15^\circ 2\Theta$  indicating the lamellar thickness. The position of this peak is the same also for amorphous  $\text{MgCl}_2$  even if it is much lower. The results showed that there had been a clear shift of the lamellar thickness indicating peak in all the X-ray diffraction patterns coming from the catalysts in this test series. In Table 8 the position of the lamellar thickness indicating peak for the catalysts in this test series is listed. In all cases the peak had shifted upwards to the region of about  $17^\circ 2\Theta$ . These results indicate that there is forming a new type of more tightly packed  $\text{MgCl}_2$  crystals in the lamellar thickness direction in the material formed in the type of stoichiometric preparation route described here (see Figure 5).

The IR spectrum of the catalyst prepared in example 6 is shown in Figure 6, and the PSD of the polymer from example 7 is shown in Figure 7, where sieve size (mm) is given in abscisse and % of polymer in ordinate.

15

**Table 8** The position of the lamellar thickness indicating peak in the X-ray diffraction pattern for crystalline  $\text{MgCl}_2$ , amorphous  $\text{MgCl}_2$  and for the catalysts of examples 5 to 8.

| <b>Material</b>             | <b>Position of the lamellar thickness indicating peak</b> |
|-----------------------------|---|
| Crystalline $\text{MgCl}_2$ | $15.0^\circ 2\Theta$                                      |
| Amorphous $\text{MgCl}_2$   | $15.0^\circ 2\Theta$                                      |
| Example 5                   | $17.1^\circ 2\Theta$                                      |
| Example 6                   | $17.0^\circ 2\Theta$                                      |
| Example 7                   | $16.5^\circ 2\Theta$                                      |
| Example 8                   | $16.1^\circ 2\Theta$                                      |

20

Figure 6 shows the IR spectrum for the catalyst of example 6.

The polymerization results are listed in Table 9 together with a description of the polymer morphology.

25

**Table 9** The polymers and their bulk density

| <b>Example</b> | <b>Bulk density<br/>(kg/m<sup>3</sup>)</b> |
|----------------|--|
| 4b             | 470  |
| 6              | 290  |
| 7              | 310  |
| 8              | 300  |

The first polymer (example 4b) showed a broad particle size distribution (PSD). The highest BD (470 kg/m<sup>3</sup>) was seen in this material. The morphology improved greatly when the heptane addition was left out in the precipitation step. The improvement was seen already when preparing the catalyst, as a catalyst precipitate that had much better settling properties was achieved. The same improvement was then seen in the morphology of the polymer that was produced when using this catalyst in the test polymerization. Over 65% of the material of example 6 has a particle size that is between 0.5 mm and 1.0 mm. The amount of fines (defined as particles below 0.1 mm) is below 1%. The amount of particles having a particle size of over 2 mm is also low, i.e. around 1%.

### 15 **Examples 9 to 13**

The experimental setups for examples 9-13 are listed in Tables 10-14 and the results are listed in Table 15.

### 20 **Preparation of the catalysts**

40.0 ml (35.01 mmol) of MgR<sub>2</sub> was added into a glass reactor. 11.0 ml (70.01 mmol) of EHA was added into the reactor and allowed to react with the MgR<sub>2</sub>. The reactants were allowed to react with each other for 30 min. After this, 17.50 mmol of the second alcohol component was added according to the description. To ensure full equilibrium, the reactants were allowed to react with each other for 30 min. 2.52 (17.50 mmol) of PDC was added and allowed to react for 30 min. The last component to be added in the Mg complex was BuCl, 4.00 ml (38.28 mmol) of this substance was added and allowed to react for 20 min. All reaction steps were carried out at a temperature of 60 °C. Last, the heptane of the MgR<sub>2</sub> solution was evaporated away at 107 °C and replaced with 10 ml (94 mmol) of toluene. The formed Mg complex was now added dropwise to 38.48 ml (350.1

mmol) of  $\text{TiCl}_4$  at 110 °C. The components were allowed to react for 5 min after which 100 ml (938 mmol) of toluene was added. The components were allowed to react for 30 min after which mixing was stopped and the catalyst was allowed to settle. Both the settling time and the precipitate volume were recorded. After siphoning off the reaction solution, the catalyst was washed first with a 10 V-%  $\text{TiCl}_4$  solution of toluene, twice with heptane and last with pentane. The washings were carried out as stated in Table 10. Finally the catalysts were dried under a stream of nitrogen.

10 Table 10

| Example 9                       | mol.ratio |          | mmol     |         |
|---------------------------------|-----------|----------|----------|---------|
| BOMAG-A® (20%/C7)               | 1         | 35.01    | 40.00 ml |         |
| EHA                             | 2         | 70.01    | 11.00 ml |         |
| BEPD                            | 0.5       | 17.50    | 2.81 g   |         |
| PDC                             | 0.5       | 17.50    | 2.52 ml  |         |
| BuCl                            | 1.1       | 38.285   | 4.00 ml  |         |
| EVAPORATION                     |           | condense | 30.33 g  |         |
| Toluene                         |           |          | 5 ml     |         |
| $\text{TiCl}_4$ (110°C)         | 10        | 350.1    | 38.48 ml |         |
| Washings:                       | stirr.    | settl.   | ml       | °C      |
|                                 | (min)     | (min)    |          |         |
| Settling                        | 0         | 15       |          | 90...70 |
| Toluene                         | 30        | 30       | 130      | 90      |
| Toluene (+10% $\text{TiCl}_4$ ) | 45        | 970      | 120      | 90      |
| C7                              | 35        | 10       | 180      | 90      |
| C7                              | 28        | 15       | 170      | 90      |
| C5                              | 20        | 1063     | 150      | 22      |
| Drying ( $\text{N}_2$ ) 75min   |           |          |          | 22→60   |

Table 11

| Example 10                        | mol.ratio       | mmol            | ml    |       |
|-----------------------------------|-----------------|-----------------|-------|-------|
| BOMAG-A® (20%/C7)                 | 1               | 35.01           | 40.00 |       |
| EHA                               | 2               | 70.01           | 11.00 |       |
| EG                                | 0.5             | 17.50           | 0.98  |       |
| PDC                               | 0.5             | 17.50           | 2.52  |       |
| BuCl                              | 1.1             | 38.28           | 4.00  |       |
| EVAPORATION                       |                 |                 |       |       |
| Toluene                           |                 |                 | 5.0   |       |
| TiCl <sub>4</sub> (110°C)         | 10              | 350.1           | 38.48 |       |
| <hr/>                             |                 |                 |       |       |
| Washings:                         | stirr.<br>(min) | settl.<br>(min) | ml    | °C    |
| Toluene                           | 35              | 10              | 200   | 90    |
| Toluene (+10% TiCl <sub>4</sub> ) | 30              | 5               | 185   | 90    |
| C7                                | 16              | 4               | 170   | 90    |
| C7                                | 22              | 4               | 180   | 90    |
| C5                                | 25              | 5               | 210   | 22    |
| Drying (N <sub>2</sub> ) 15 min   |                 |                 |       | 22→60 |

Table 12

5

| Example 11                        | mol.ratio       | mmol            | ml       |       |
|-----------------------------------|-----------------|-----------------|----------|-------|
| BOMAG-A® (20%/C7)                 | 1               | 35.01           | 40.00    |       |
| EHA                               | 2               | 70.01           | 11.00    |       |
| EG                                | 0.5             | 17.50           | 0.98     |       |
| PDC                               | 0.5             | 17.50           | 2.52     |       |
| BOMAG-A® (20%/C7)                 | 0.4             | 14.00           | 16.0     |       |
| BuCl                              | 1.1             | 38.28           | 4.00     |       |
| EVAPORATION                       |                 |                 | condense |       |
| Toluene                           |                 |                 | 15       |       |
| TiCl <sub>4</sub> (110°C)         | 10              | 350.1           | 38.48    |       |
| <hr/>                             |                 |                 |          |       |
| Cooling                           |                 |                 |          |       |
| Washings:                         | stirr.<br>(min) | settl.<br>(min) | ml       | °C    |
| Toluene                           | 30              | 15              | 120      | 90    |
| Toluene (+10% TiCl <sub>4</sub> ) | 31              | 6               | 135      | 90    |
| C7                                | 05              | 970             | 150      | 90    |
| C7                                | 25              | 8               | 205      | 90    |
| C5                                | 18              | 4               | 210      | 22    |
| Drying (N <sub>2</sub> ) 37 min   |                 |                 |          | 22→60 |

Table 13

| <b>Example 12</b>                 | <b>mol.ratio</b> | <b>mmol</b>   | <b>ml</b> |           |
|-----------------------------------|------------------|---------------|-----------|-----------|
| BOMAG-A® (20%/C7)                 | 1                | 35.01         | 40.00     |           |
| EHA                               | 2                | 70.01         | 11.00     |           |
| Glycerol                          | 0.5              | 17.50         | 1.29      |           |
| PDC                               | 0.5              | 17.50         | 2.52      |           |
| BuCl                              | 1.1              | 38.29         | 4.00      |           |
| EVAPORATION                       |                  |               |           | condense  |
| Toluene                           |                  |               | 15.0      |           |
| TiCl <sub>4</sub> (110°C)         | 10               | 350.1         | 38.48     |           |
| <b>Washings:</b>                  | <b>stirr.</b>    | <b>settl.</b> | <b>ml</b> | <b>°C</b> |
|                                   | <b>(min)</b>     | <b>(min)</b>  |           |           |
| Toluene                           | 28               | 12            | 120       | 107       |
| Toluene (+10% TiCl <sub>4</sub> ) | 20               | 21            | 140       | 90        |
| C7                                | 26               | 11            | 150       | 90        |
| C7                                | 24               | 22            | 165       | 90        |
| C5                                | 15               | 9             | 170       | 22        |
| Drying (N <sub>2</sub> ) 36 min   |                  |               |           | 22→60     |

Table 14

| Example 13                | mol.ratio | mmol   | ml    |
|---------------------------|-----------|--------|-------|
| BOMAG-A® (20%/C7)         | 1         | 35.01  | 40.00 |
| EHA                       | 2.5       | 87.52  | 13.75 |
| EtOH                      | 0.1       | 3.50   | 0.20  |
| EG                        | 0.05      | 1.75   | 0.10  |
| PDC                       | 0.5       | 17.50  | 2.52  |
| BOMAG-A® (20%/C7)         | 0.2       | 7.00   | 8.00  |
| i-PDC                     | 0.05      | 1.75   | 0.36  |
| BuCl                      | 1.1       | 38.28  | 4.00  |
| EVAPORATION               |           |        |       |
| Toluene                   |           |        | 10    |
| TiCl <sub>4</sub> (110°C) | 10        | 350.06 | 38.48 |

Cooling

| Washings:                         | stirr.<br>(min) | settl.<br>(min) | ml  | °C    |
|-----------------------------------|-----------------|-----------------|-----|-------|
| Toluene                           | 27              | 25              | 80  | 90    |
| Toluene (+10% TiCl <sub>4</sub> ) | 23              | 20              | 140 | 90    |
| C7                                | 25              | 14              | 150 | 90    |
| C7                                | 30              | 968             | 190 | 90    |
| C5                                | 27              | 22              | 175 | 22    |
| Drying (N <sub>2</sub> ) 40 min   |                 |                 |     | 22→60 |

Table 15

| Catalyst                    | Example 9 | Example 10 | Example 11 | Example 12 | Example 13 |
|-----------------------------|-----------|------------|------------|------------|------------|
| Mg (wt-%)                   | 16.3      | 14.1       | 14.1       | 13.7       | 13.9       |
| Mg (mol/100 g catalyst )    | 0.671     | 0.580      | 0.580      | 0.564      | 0.572      |
| Ti (wt-%)                   | 3.3       | 3.0        | 7.1        | 3.3        | 2.7        |
| Ti (mol/100 g catalyst )    | 0.069     | 0.063      | 0.148      | 0.069      | 0.056      |
| BEPD (wt-%)                 | 2.2       |            |            |            |            |
| BEPD (mol/100 g catalyst )  | 0.014     |            |            |            |            |
| EHA (wt-%)                  | 0.3       | 0.35       | 2.8        | 2.8        | 1.1        |
| EHA (mol/100 g catalyst )   | 0.0023    | 0.0027     | 0.0215     | 0.0215     | 0.0084     |
| DOP (wt-%)                  | 27.7      | 17.6       | 18.4       | 23.2       | 21.8       |
| DOP (mol/100 g catalyst )   | 0.071     | 0.045      | 0.047      | 0.059      | 0.056      |
| Mg (mol Mg/mol Ti)          | 9.7       | 9.3        | 3.9        | 8.2        | 10.1       |
| Donor (mol Donor/mol Ti)    | 1.0       | 0.7        | 0.3        | 0.9        | 1.0        |
| Diol                        | BEPD      | EG         | EG         | Glycerol   | EG+EtOH    |
| Activ. (kg PP/g cat)        | 26.0      | 33.8       | 13.1       | 21.2       | 20.0       |
| Activ. (kg PP/g Ti)         | 788       | 1127       | 184        | 642        | 743        |
| BB (kg/m <sup>3</sup> )     | 330       | 380        | 410        | 310        | 380        |
| MFR <sub>2</sub> (g/10 min) | 8.8       | 6.7        | 7.5        | 7.9        | 11.4       |
| XS (wt-%)                   | 4.1       | 2.75       |            |            |            |

The resulting yields in the catalyst synthesis were in general high.

5

The amounts of Ti in these catalysts are also shown in Figure 8.

No additional amount of DEP could be found in the catalyst of example 13. This example was the only one where DEP could be expected to be found because some ethanol had been added.

10

The % of polymer (= di-, oligo- or polyester), calculated as 100 % - % known species are correlated to the number of -OH groups in the added alcohol in Figure 9, where (1) refers to EHA, (2) to ethylene glycol and (3) to glycerol.

15

The molar ratios between Mg, Ti and the donor are shown in Figure 10, where Ti is presented in the first column, Mg in the second column and donor in the third column. The Figure shows that the catalysts can be divided into two groups, one

group where the Mg:Ti:Donor ratio is close to 9:1:1 and a second group where less Mg is present.

The activities of the catalysts are shown in Figure 11 in kg PP/g.cat. The catalysts  
5 can be divided into two groups depending on their activity, one group showing a high activity of above 20 kg PP/g cat and a second group showing lower activity.

The particle size distribution (PSD) of the polymer sample was measured using a  
10 Fritsch Pulverisette equipment with a sieving set consisting of 5, 4, 2, 1, 0.5, 0.18, 0.1, 0.056, 0.036 mm sieves and <0.036 mm (pan).

Figures 12a-12e shows the PSD (particle size distribution) diagrams for the five  
15 polymers achieved with the catalysts in this test series. The results showed that the catalysts of examples 10, 11 and 12, showed a clearly narrower PSD compared to the catalysts of examples 9 and 13.

A more narrow particle size distribution (PSD) can be produced with ethylene glycol. The main particle size (PS) is then 1 mm.

20 Very good activities can be reached when using ethylene glycol in the catalyst synthesis. Activities of almost 34 kg PP/g cat were achieved.

#### Examples 14 to 17

25 All the chemicals used were identical to the chemicals used in previous examples. The only chemical not defined earlier but used in this study was 1,4-dichlorobutane (DCB) that was used as a reactive halogenated hydrocarbon.

#### Preparation of the catalysts

30

The preparation of the catalysts was started by adding 40.0 ml (35.01 mmol) of MgR<sub>2</sub> (BOMAG-A®) to a 250 ml glass reactor. To this a mixture of both the mono alcohol and the diol, i.e. 11.0 ml (70.01 mmol) of EHA and 17.50 mmol of either BEPD or EG was added. The temperature of the reaction solution was increased to  
35 60 °C and the reaction components were allowed to react with each other for 30 min. After this 2.52 ml (17.50 mmol) of PDC was added at 25 °C. Again, the temperature was raised to 60 °C and the components allowed to react for 30 min. The heptane was now evaporated from the reaction solution at a temperature of 105

°C, this to improve the reaction possibilities for the chlorinated hydrocarbons. After the evaporation of the heptane 45.67 mmol (5.0 ml) of either BuCl or DCB was added. The molar ratio between Mg and the chlorination agent was thus about 1:1.3 in both cases. After a 30 min reaction time 20.0 ml (188 mmol) of toluene was added. This Mg complex solution was then added dropwise to 38.48 ml (350.1 mmol) of TiCl<sub>4</sub> at 110 °C. The components were allowed to react with each other for 10 min after which the solution was cooled down to 105 °C and 150 ml of toluene was added. After this the formed precipitate was allowed to settle. The settling time and the precipitate volume were recorded. When the settling step was complete the clear solution was siphoned off and the precipitate washed first once with 150 ml of toluene at 90 °C for 30 min, then twice with 150 ml of heptane at 90 °C for 30 min and last with 150 ml of pentane at room temperature for 20 min. Last, the catalyst was dried under a stream of nitrogen. The experimental setup, i.e. when BEPD or EG or when ButCl or DCB have been used in this test series, are listed in Table 16.

Table 16 The experimental setup of examples 14 to 17

| Example | Diol used | Chlorinated hydrocarbon used |
|---------|-----------|------------------------------|
| 14      | BEPD      | DCB                          |
| 15      | EG        | DCB                          |
| 16      | BEPD      | BuCl                         |
| 17      | EG        | BuCl                         |

The yield of the catalyst mass from the catalyst synthesis was calculated on the basis of how much Mg was fed into the synthesis in the form of MgR<sub>2</sub> (0.8507 g) and by comparing this amount with the amount of Mg found in the resulting catalyst. The results are listed in Table 17. In Tables 18, 19 and 20 are listed the results of the catalyst analyzes: Mg, Ti and DOP %, molar ratios Mg:Ti:DOP and calculated and measured Cl contents, respectively.

**Table 17** The yield per cent of the catalysts of examples 14 to 17

| <b>Example</b> | <b>Yield of catalyst (g)</b> | <b>Calculated yield<sup>1</sup></b> |
|----------------|------------------------------|-------------------------------------|
| 14             | 6.0                          | 91                                  |
| 15             | 3.4                          | 69                                  |
| 16             | 5.7                          | 99                                  |
| 17             | 6.8                          | 98                                  |

<sup>1</sup>) Calculations based on: Yield % = (Catalyst yield (g) \* Mg %)/0.8507 (g)

5

**Table 18** The Mg, Ti and DOP in the catalysts of examples 14 to 17

| <b>Example</b>           | <b>14</b> | <b>15</b> | <b>16</b> | <b>17</b> |
|--------------------------|-----------|-----------|-----------|-----------|
| Mg (wt-%)                | 12.9      | 17.3      | 14.9      | 12.2      |
| Mg (mol/100g catalyst)   | 0.53      | 0.71      | 0.61      | 0.50      |
| Ti (wt-%)                | 3.6       | 3.7       | 2.2       | 4.1       |
| Ti (mol/100 g catalyst)  | 0.08      | 0.08      | 0.05      | 0.09      |
| DOP (wt-%)               | 30.9      | 22.4      | 27.9      | 29.8      |
| DOP (mol/100 g catalyst) | 0.08      | 0.06      | 0.07      | 0.08      |

**Table 19** The molar ratios between Mg:Ti:DOP in the catalysts of examples 14 to 17

10

| <b>Examples</b> | <b>14</b> | <b>15</b> | <b>16</b> | <b>17</b> |
|-----------------|-----------|-----------|-----------|-----------|
| Mg              | 7.1       | 9.2       | 13.4      | 5.9       |
| Ti              | 1         | 1         | 1         | 1         |
| DOP             | 1.05      | 0.74      | 1.56      | 0.89      |

**Table 20** The calculated amount of Cl compared to the measured amounts of Cl in examples 14 to 17

15

| <b>Example</b>        | <b>14</b> | <b>15</b> | <b>16</b> | <b>17</b> |
|-----------------------|-----------|-----------|-----------|-----------|
| Cl (wt-%), calculated | 37.7      | 50.5      | 43.5      | 35.6      |
| Cl (wt-%), measured   | 47.1      | 50.5      | 52.5      | 48.8      |

The polymerization results are listed in Table 21 together with figures about the MFR and BD of the polymers.

**Table 21** Test polymerization results from bulk test polymerization of examples 14 to 17

| <b>Example</b>          | <b>14</b> | <b>15</b> | <b>16</b> | <b>17</b> |
|-------------------------|-----------|-----------|-----------|-----------|
| Activity (kg PP/g cat.) | 24.1      | 28.0      | 21.8      | 23.0      |
| Activity (kg PP/g Ti)   | 669       | 758       | 989       | 562       |
| MFR 2.16 kg (g/10 min)  | 6.3       | 8.3       | 8.4       | 7.4       |
| BD (kg/m <sup>3</sup> ) | 290       | 310       | 300       | 410       |

5 The polymerization results showed that if the BEPD diol is exchanged to EG, this has a positive effect on the activity of the catalyst. In the case BuCl was used as chlorinated hydrocarbon there was an activity increase from 21.8 to 23.0 kg PP/g cat., and if the DCB had been used as the chlorinated hydrocarbon there was an activity increase from 21.8 to 28.0 kg PP/g cat., thus showing a 28% activity  
10 increase in the best case.

The polymerization results also showed that when using the DCB as chlorinated hydrocarbon a higher activity was achieved compared to when using BuCl. This was the case both when using BEPD and when using EG as diol. In the former case  
15 the activity increased from 21.8 to 24.1 kg PP/g cat, and in the later case the activity increased from 23.0 to 28.0 kg PP/g cat, i.e. a 22 % increase in activity.

In Table 22 the Mg/Ti molar ratio in the catalysts is compared to the activities of the catalysts. According to the results there is a steady growth in activity the higher the  
20 Mg/Ti molar ratio. Here an increase in activity from 23.0 kg PP/g cat for the ratio of 5.9 to 28.0 kg PP/g cat for the Mg/Ti ratio of 9.2 is seen.

**Table 22** The molar ratios between Mg:Ti in the catalysts and their activities

| <b>Example</b>          | <b>14</b> | <b>15</b> | <b>16</b> | <b>17</b> |
|-------------------------|-----------|-----------|-----------|-----------|
| Mg/Ti                   | 7.1       | 9.2       | 13.4      | 5.9       |
| Activity (kg PP/g cat.) | 24.1      | 28.0      | 21.8      | 23.0      |
| Activity (kg PP/g Ti)   | 669       | 758       | 989       | 562       |

25

In Table 23 the DOP/Ti molar ratio is listed together with the activity values for the catalysts. The results showed that the lower the DOP/Ti ratio the higher the activity. In Table 23 an increase in activity from 21.8 kg PP/g cat to 28.0 kg PP/g cat is seen when the molar ratio of DOP/Ti decreases from 1.6 to 0.7.

**Table 23** Correlation between the DOP/Ti ratio and the activity of the catalysts

| <b>Example</b> | <b>DOP/Ti (mol/mol)</b> | <b>Activity (kg PP/g cat)</b> |
|----------------|-------------------------|-------------------------------|
| 14             | 0.7                     | 24.1                          |
| 15             | 0.9                     | 28.0                          |
| 16             | 1.0                     | 21.8                          |
| 17             | 1.6                     | 23.0                          |

In Table 24 the particle size fractions in the test polymers are listed.

5

**Table 24** The PS fractions in the test polymers of examples 14 to 17, in % of polymer on sieve

| <b>Example</b>       | <b>14</b> | <b>15</b> | <b>16</b> | <b>17</b> |
|----------------------|-----------|-----------|-----------|-----------|
| <b>Sieve size/mm</b> |           |           |           |           |
| 5.0                  | 9.5       | 5.7       | 1.3       | 2.3       |
| 4.0                  | 2.1       | 1.7       | 0.2       | 3.5       |
| 2.0                  | 4.6       | 9.3       | 1.8       | 26.0      |
| 1.0                  | 4.6       | 16.4      | 2.3       | 27.3      |
| 0.5                  | 6.8       | 16.2      | 11.0      | 16.2      |
| 0.18                 | 45.8      | 25.2      | 76.4      | 18.6      |
| 0.10                 | 19.0      | 19.1      | 6.2       | 5.0       |
| 0.056                | 7.0       | 6.4       | 0.8       | 1.0       |
| 0.036                | 0.6       | 0.2       | 0.1       | 0.1       |
| <0.036               | 0.0       | 0.0       | 0.0       | 0.0       |

- 10 The results showed a drastic difference in the PSD depending on which diol had been used. If BEPD had been used the main PS fraction was on the 0.18 mm sieve, if EG had been used the main PS fraction was on the 1 to 0.18 mm sieve. This effect was even more pronounced when BuCl had been used as chlorination agent compared to DCB. The results also showed that if BEPD had been used, the PSD
- 15 was very sharp, up to 75% of the particles could be found on one sieve, the 0.18 mm sieve. Again if EG had been used the PSD was much broader and only about 25% of the material could be found on the main sieve, i.e. the 1 mm sieve. This can clearly be seen in Table 25 where the per cent material representing the biggest fractions in the polymer PSD are listed (i.e. the fractions on the 0.18 mm
- 20 and the 1 mm sieves).

**Table 25** The per cent of the polymer material in the two main fractions of the PSD

| <b>Example</b> | <b>% at 0.18 mm sieve</b> | <b>% at 1 mm sieve</b> |
|----------------|---------------------------|------------------------|
| 14             | 45.8                      | 4.6                    |
| 15             | 25.2                      | 16.4                   |
| 16             | 76.4                      | 2.3                    |
| 17             | 18.6                      | 27.3                   |

For comparison a catalyst was prepared in the absence of diol. When this kind of catalyst is used in polymerization the polymer particles tend to form agglomerates giving a broad PSD of the resulting polymer material. This is shown in a polymer PSD that has been produced with said catalyst. When replacing a part of the monoalcohol (EHA) used in this recipe with a diol a much narrower PSD can be achieved. The recipe is presented in Table 26 and the results of the sieve operation is presented in Table 27.

**Table 26**

| <b>Comparative example</b> | <b>mole ratio</b> | <b>mmol</b> | <b>ml</b> |
|----------------------------|-------------------|-------------|-----------|
| BOMAG-A® (20%/C7)          | 1                 | 26.55       | 30.0      |
| EHA                        | 2                 | 53.10       | 8.3       |
| PDC                        | 1                 | 26.55       | 3.8       |
| TiCl <sub>4</sub> (95°C)   | 10                | 265.5       | 29.2      |
| Toluene                    |                   |             | 80+60     |

| <b>Washings:</b>                | <b>Time (min)</b> | <b>ml</b> | <b>°C</b> |
|---------------------------------|-------------------|-----------|-----------|
| Toluene                         | 50                | 148       | 90        |
| Toluene                         | 15                | 56        | 22→85     |
| C7                              | 32                | 68        | 22→85     |
| C7                              | 32                | 50        | <35       |
| C5                              | 15                | 60        | 22        |
| Drying (N <sub>2</sub> ) 42 min |                   |           | 22→55     |

Table 27

| Sieve size/mm | wt-% |
|---------------|------|
| 5.0           | 11   |
| 4.0           | 3    |
| 2.0           | 9    |
| 1.0           | 14   |
| 0.5           | 22   |
| 0.18          | 30   |
| 0.10          | 8    |
| 0.056         | 2    |
| 0.036         | 0    |
| <0.036        | 0    |

The bulk density values (BD) for the polymers listed in Table 21 showed that there was a strong correlation between the bulk density and the diol used in the synthesis. If EG had been used the BD was higher. This shows up as a BD increase from 290 to 310 when going from example 14 to example 17, i.e. from BEPD to EG and as a BD increase from 300 to 410 when going from example 16 to example 17, i.e. from BEPD to EG.

10

### Conclusions

1. (1,4)-butyl-dichloride gives up to 20% higher activity to the catalyst compared to BuCl
2. EG gives 30% higher catalyst activity compared to BEPD
3. EG gives a coarse and a fine catalyst precipitate fraction, BEPD gives only a fine
4. EG gives faster settling time for the catalyst precipitate, BEPD gives slower settling time
5. EG gives smaller catalyst precipitate volume than BEPD
6. EG gives main PS of PP at 1 mm, BEPD at 0.18 mm
7. BEPD gives very narrow PSD of PP at 0.18 mm, EG gives broad at 1 mm
8. EG gives BD of 400, BEPD gives BD of 300
9. Optimum Mg/Ti is about 9
10. Optimum DOP/Ti is between 0.7 and 1.3

## Examples 18 and 19

All the chemicals used were identical to the chemicals used in previous examples, except for the magnesium dichloride  $MgCl_2$ .

5

### Preparation of the catalysts

The preparation of the catalysts was started by adding 1,2 g (12,6 mmol) of  $MgCl_2$ , 2,1 g (13,1 mmol) BEPD and 8,2 ml (52,5 mmol) EHA to a glass reactor equipped with a magnetic stirrer. The mixture was heated up to 145 °C and mixed until a clear solution was obtained. The solution was cooled down and 2 ml of toluene was added.

10

Half of the solution was taken into a 50 ml glass reactor equipped with a stirrer. 18.0 ml (15.8 mmol) in example 18 and 16.0 ml (14 mmol) in example 19 of  $MgR_2$  (BOMAG-A®) was added while the temperature was kept between 5 to 10 °C. The temperature of the reaction solution was increased to 60 °C and 1.0 ml (7.0 mmol) of PDC was added. After the reaction was completed, 1.5 ml (14.3 mmol) BuCl was added. After 5 min the temperature was raised to 95-97 °C and about half of the liquid was evaporated with nitrogen stream. After evaporation 4.0 ml of toluene was added and the solution was then cooled down to room temperature.

20

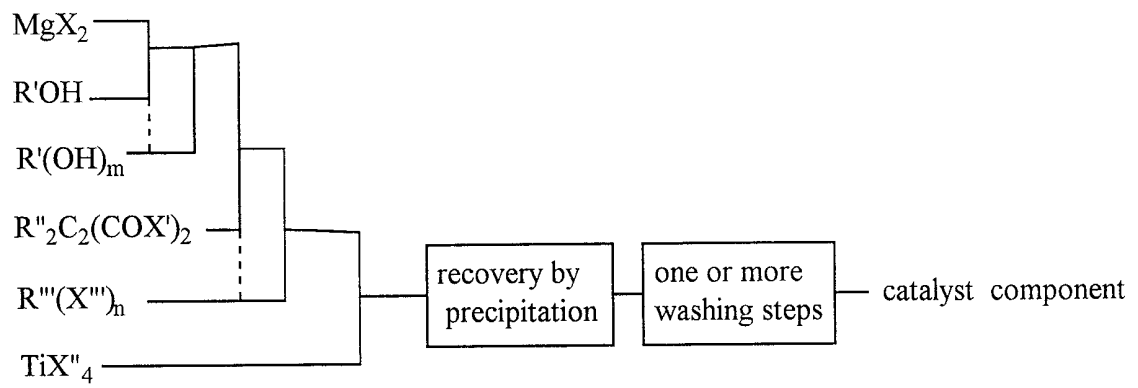
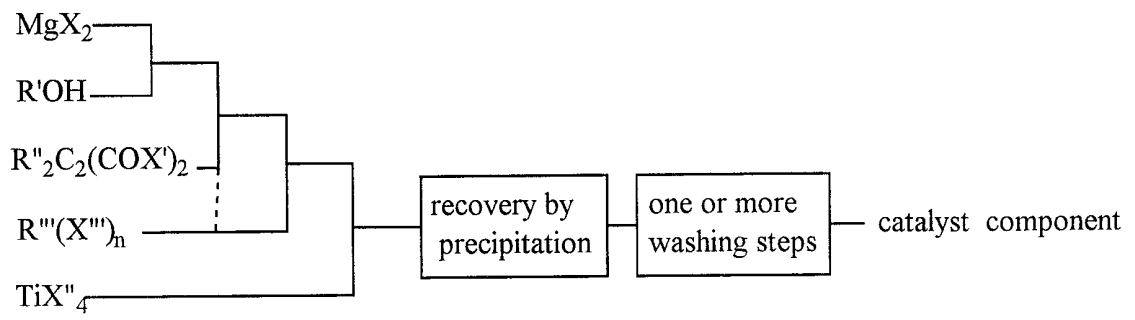
This Mg complex solution was then added dropwise to 15.0 ml (136 mmol) of  $TiCl_4$  at 110 °C. The components were allowed to react with each other for 15 min after which the solution was cooled down to 90 °C and 20 ml of toluene was added. After one hour, the formed precipitate was allowed to settle. When the settling step was complete the clear solution was siphoned off and the precipitate washed first once with toluene at 90 °C, then twice with heptane at 90 °C. Last, the catalyst was dried under a stream of nitrogen. The results are summarized in Table 28.

25

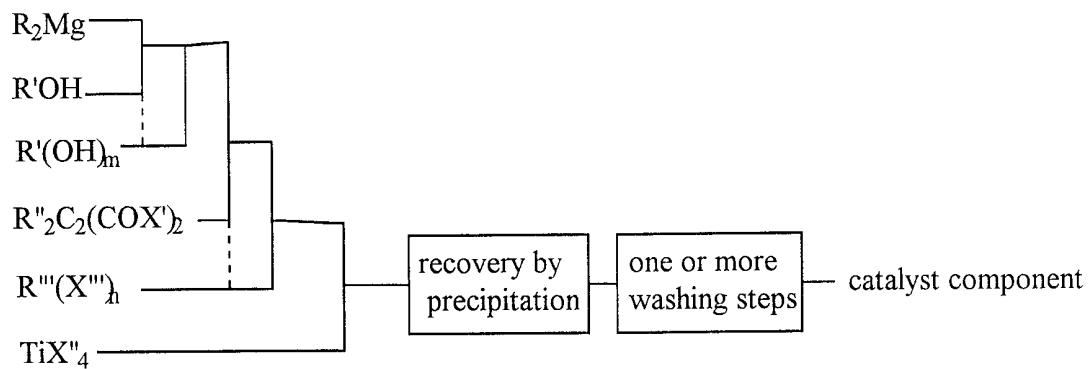
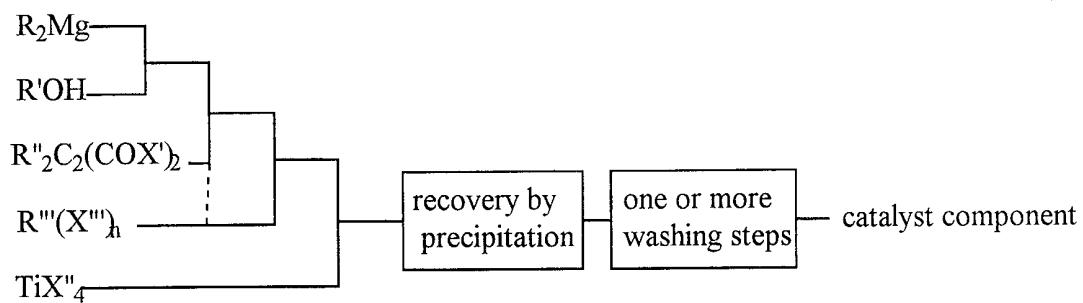
30

**Table 28**

| <b>Catalyst</b>             | <b>Example 18</b> | <b>Example 19</b> |
|-----------------------------|-------------------|-------------------|
| Mg (wt-%)                   | 12.4              | 14.3              |
| Ti (wt-%)                   | 5.4               | 2.3               |
| DOP (wt-%)                  | 24.1              | 29.5              |
| DEP (wt-%w-%)               |                   |                   |
| Activ. (kg PP/g cat)        | 23.4              | 16.4              |
| BD (kg/m <sup>3</sup> )     | 430               | 420               |
| MFR <sub>2</sub> (g/10 min) | 5.6               | 5.9               |
| XS (wt-%)                   | 2.6               | 3.8               |



Appendix 1. Two embodiments starting from  $MgX_2$



Appendix 2. Two embodiments starting from  $R_2Mg$

## Claims

1. A process for the preparation of an olefin polymerization catalyst component comprising a magnesium dihalide, a titanium tetrahalide, and a dicarboxylic acid diester as internal electron donor ED, characterized by the steps of:

(i) providing a magnesium compound (ab) containing an alkoxy moiety, selected from the group consisting of a magnesium dialkoxide, a complex containing a magnesium dihalide and an alcohol, and a complex containing a magnesium dihalide and a magnesium dialkoxide, and

(ii) reacting said magnesium compound (ab) with at least one dicarboxylic acid dihalide (c) which forms said dicarboxylic acid diester as internal donor ED and has the formula (1):

15



wherein each R'' is a similar or different C<sub>1</sub>-C<sub>20</sub> hydrocarbyl group or both R''s form together with the two unsaturated carbons of the formula a C<sub>5</sub>-C<sub>20</sub> aliphatic or aromatic ring, and X' is a halogen, to give an intermediate (abc),

(iii) reacting said intermediate (abc) with at least one titanium tetrahalide TiX''<sub>4</sub> (d) wherein X'' is a halogen,

25

(iv) recovering said catalyst component in crude form or recovering a precursor of said catalyst component, and

(v) optionally washing said crude catalyst component or said precursor, to give said catalyst component, and

30

by adding and reacting in connection with the above step (ii) or (iii) at least one halogenated hydrocarbon (e) of the formula (2)



wherein R'' is an n-valent C<sub>1</sub>-C<sub>20</sub> hydrocarbyl group, X'' is a halogen and n is an integer selected from 1, 2, 3 and 4.

5

2. A process according to claim 1, **characterized** in that at least one, preferably all of steps (i) to (iii), are performed in solution, preferably by using one or several hydrocarbon solvents and optionally applying stirring and/or heat.

10 3. A process according to claim 2, **characterized** in that in step (iv), said catalyst component is recovered by precipitation.

4. A process according to claim 1, 2 or 3, **characterized** in that in said reactive halogenated hydrocarbon (e) of formula (2), R'' is a mono or bivalent C<sub>1</sub>-C<sub>10</sub> hydrocarbyl group, X'' is chlorine and n is 1 or 2, preferably that said hydrocarbyl halide (e) is a butyl chloride or (1,4)-dichlorobutane, most preferably that it is tertiary butyl chloride or (1,4)-dichlorobutane.

15 5. A process according to any preceding claim, **characterized** in that said reactive halogenated hydrocarbon (e) is added in an amount corresponding to a molar ratio Mg<sub>total added</sub>/(e) of between 1:0.2 and 1:20, preferably between about 1:1 and about 1:4.

20 6. A process according to any preceding claim, **characterized** in that said magnesium compound (ab) containing an alkoxy moiety is provided by reacting at least one magnesium compound precursor (a), selected from the group consisting of a dialkyl magnesium R<sub>2</sub>Mg, an alkyl magnesium alkoxide, wherein each R is a similar or different C<sub>1</sub>-C<sub>20</sub> alkyl, and a magnesium dihalide MgX<sub>2</sub>, wherein X is a halogen with at least one alcohol (b), selected from the group consisting of monohydric alcohols R'OH and polyhydric alcohols R'(OH)<sub>m</sub>, wherein R' is an

30 7. A process according to any preceding claim, **characterized** in that said magnesium compound precursor (a) is a dialkyl magnesium R<sub>2</sub>Mg, in which each R is a similar or different C<sub>4</sub>-C<sub>12</sub> alkyl group, preferably in which one R is a butyl group and the other R is an octyl group.

8. A process according to any preceding claim, **characterized** in that said magnesium compound precursor (a) is a magnesium dihalide, which is magnesium dichloride.
- 5 9. A process according to any preceding claim, **characterized** in that said magnesium compound (ab) is provided by reacting, in any order, a dialkyl magnesium  $R_2Mg$  and a magnesium dihalide  $MgX_2$  with at least one alcohol (b), selected from the consisting of monohydric alcohols  $R'OH$  and polyhydric alcohols  $R'(OH)_m$ , wherein  $R'$  is an 1-valent or, respectively, an m-valent  $C_1-C_{20}$  hydro-  
10 carbonyl group and m is an integer selected from 2, 3, 4, 5 and 6.
10. A process according to any preceding claim, **characterized** in that said alcohol (b) is a monohydric alcohol  $R'OH$  in which  $R'$  is a  $C_2-C_{16}$  alkyl group, preferably a  $C_4-C_{12}$  alkyl group, or most preferably that said alcohol (b) is 2-ethyl-1-hexanol.
- 15 11. A process according to any preceding claim, **characterized** in that said magnesium compound (a) is in step (i) reacted with said alcohol (b) which is said monohydric alcohol  $R'OH$ , in a molar ratio  $Mg/ROH$  of between 1:4 and 1:1, preferably between about 1:2.5 and about 1:1.5.
- 20 12. A process according to any preceding claim, **characterized** in that said alcohol (b) is a polyhydric alcohol  $R'(OH)_m$ , wherein  $R'$  is a di, tri or tetravalent  $C_2-C_{16}$  alkyl group and m is an integer selected from 2, 3 and 4, preferably a polyhydric alcohol selected from the group consisting of ethylene glycol, 2-butyl-2-ethyl-1,3-  
25 propanediol and glycerol.
13. A process according to any preceding claim, **characterized** in that in step (i), said magnesium compound precursor (a) is reacted with said alcohol (b) which is said polyhydric alcohol  $R'(OH)_m$  in a molar ratio  $Mg/R'(OH)_m$  of between 1:1 and  
30 1:0.25, preferably between about 1:0.8 and about 1:0.3.
14. A process according to any preceding claim, **characterized** in that in step (i), said magnesium compound precursor (a) is reacted with at least two of said alcohols (b), one of which is said monohydric alcohol  $R'OH$  and the other of which is said  
35 polyhydric alcohol  $R'(OH)_m$ .

15. A process according to any preceding claim, **characterized** in that in step (i), said magnesium compound precursor (a) is reacted with said at least one alcohol (b), under at least one of the following conditions:

- 5
- at raised temperature, preferably at about 30 °C to about 80 °C,
  - for a period of about 10 min to about 90 min, preferably about 30 min,
  - in the presence of a C<sub>5</sub>-C<sub>10</sub> hydrocarbon solvent, preferably heptane.

10 16. A process according to any preceding claim, **characterized** in that in said dicarboxylic acid dihalide (c) of the formula (1), both R<sup>2</sup>'s form together with the two unsaturated carbons of said formula (1) a C<sub>5</sub>-C<sub>20</sub> aliphatic or a C<sub>6</sub>-C<sub>20</sub> aromatic ring, and X' is chlorine, preferably that said dicarboxylic acid dihalide (c) is phthaloyl dichloride.

15 17. A process according to any preceding claim, **characterized** in that in step (ii), said magnesium compound (ab) is reacted with said dicarboxylic acid dihalide (c) in a molar ratio Mg<sub>total added</sub>/(c) between 1:1 and 1:0.1, preferably between about 1:0.6 and about 1:0.25.

20 18. A process according to any preceding claim, **characterized** in that that in step (ii), said magnesium compound (ab) is reacted with said dicarboxylic acid dihalide (c), under at least one of the following conditions:

- 25
- adding said dicarboxylic acid dihalide (c) under room temperature and heating the obtained reaction mixture,
  - keeping the reactants together at raised temperature, preferably at about 30 °C to about 80 °C,
  - keeping the reactants together for a period of about 10 min to about 90 min, preferably about 30 min,
  - reacting the reactants in the presence of a C<sub>5</sub>-C<sub>10</sub> hydrocarbon solvent, preferably heptane.
- 30

35 19. A process according to claim 18, **characterized** in that after said magnesium compound (ab) has been reacted with said dicarboxylic acid dihalide (c), said C<sub>5</sub>-C<sub>10</sub> hydrocarbon solvent, preferably heptane, is removed by evaporation, preferably at about 100°C to about 110°C.

20. A process according to claim 19, **characterized** in that after said C<sub>5</sub>-C<sub>10</sub> hydrocarbon solvent, preferably said heptane, has been removed by evaporation,

said second intermediate (abc) is contacted with said reactive halogenated hydrocarbon (e), preferably for a period of about 10 min to about 90 min, preferably about 30 min.

- 5 21. A process according to claim 20, **characterized** in that after said intermediate (abc) has been contacted with said reactive halogenated hydrocarbon (e), a dissolving C<sub>5</sub>-C<sub>10</sub> hydrocarbon, preferably toluene, is added, most preferably in a molar ratio  $Mg_{\text{total added}}/\text{toluene}$  of between about 1:2 and about 1:10.
- 10 22. A process according to any preceding claim, **characterized** in that said titanium tetrahalide (d) is titanium tetrachloride.
23. A process according to any preceding claim, **characterized** in that in step (iii), said intermediate (abc) is reacted with said titanium tetrahalide (d) in a molar ratio  
15  $Mg_{\text{total added}}/(d)$  between 1:100 and 1:1, preferably between about 1:50 and about 1:5, most preferably about 1:10.
24. A process according to any preceding claim, **characterized** in that, in step (iii), said intermediate (abc), preferably a solution thereof, is added slowly,  
20 preferably dropwise, to said titanium tetrahalide (d), which preferably is hot (e.g. 110 °C), to form a solution of said catalyst component.
25. A process according to claim 21 and 24, **characterized** in that said toluene solution of said intermediate (abc) is added dropwise to said titanium tetrahalide (d)  
25 at 110 °C.
26. A process according to claim 25, **characterized** in that of said intermediate (abc) is reacted with said titanium tetrahalide (d) at 110 °C for about 5 min to about 20 min, preferably for about 10 min.
- 30 27. A process according to any preceding claim, **characterized** in that in step (iv), said catalyst component in crude form or a precursor thereof is recovered by cooling a solution of said catalyst component, preferably said toluene solution of said catalyst component, for the precipitation of said crude catalyst component or said  
35 precursor thereof and preferably allowing it to settle.
28. A process according to claim 27, **characterized** in that immediately before said precipitation, a C<sub>5</sub>-C<sub>10</sub> hydrocarbon solvent, preferably toluene, most preferably

toluene in a molar ratio  $Mg_{\text{total added}}/\text{toluene}$  of about 1:10 to about 1:100, is added to said catalyst component solution.

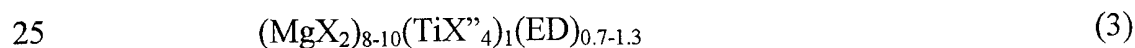
29. A process according to claim 27 or 28, **characterized** in that after said crude catalyst component or said precursor thereof has settled, the supernatant liquid is removed e.g. by decanting or siphoning.

30. A process according to any preceding claim, **characterized** in that in step (v), said recovered crude catalyst component or said precursor thereof is washed with toluene, preferably with hot (e.g. 90 °C) toluene.

31. A process according to any preceding claim, **characterized** in that in step (v), said recovered crude catalyst component or said precursor thereof is washed with heptane, preferably with hot (e.g. 90 °C) heptane.

32. A process according to any preceding claim, **characterized** in that in step (v), said recovered crude catalyst component or precursor thereof is washed with pentane.

33. A process according to any preceding claim, **characterized** in that in step (v) said recovered crude catalyst component or precursor thereof is washed to give the following ratio of said magnesium dihalide, said titanium tetrahalide, and said dicarboxylic acid diester as internal electron donor ED (3):



wherein  $MgX_2$  is said magnesium dihalide,  $TiX''_4$  is said titanium tetrahalide and ED is said dicarboxylic acid diester as internal electron donor, preferably a phthalic acid diester, whereby said recovered catalyst component is preferably washed first with toluene, more preferably hot (e.g. 90 °C) toluene, then at least twice with hot (90°) heptane, and finally with pentane.

34. A process according to any preceding claim, **characterized** in that the washed catalyst component is dried, preferably by evaporation.

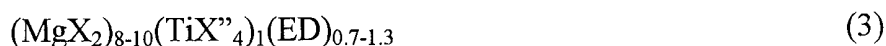
35. An olefin polymerization catalyst component comprising a magnesium dihalide, a titanium tetrahalide, and a dicarboxylic acid diester as internal electron

donor ED, **characterized** in that it has been prepared according to the process of any preceding claim.

36. A catalyst component according to claim 34, **characterized** in that it contains  
5 halogen from about 10% to about 60% more than the amount of halogen calculated on the basis of the amounts of magnesium and titanium present, assuming that all of the magnesium is in the form of said  $MgX_2$  and all of the titanium is in the form of said  $TiX_4$ , wherein X is a halogen.

10 37. A solid olefin polymerization catalyst component comprising a magnesium dihalide, a titanium tetrahalide, and a dicarboxylic acid diester as internal donor ED, **characterized** in that it is essentially homogenous and has the following ratio of said magnesium dihalide, said titanium tetrahalide, and said dicarboxylic acid diester as internal electron donor ED (3):

15



wherein  $MgX_2$  is said magnesium dihalide,  $TiX''_4$  is said titanium tetrahalide, X and/or  $X''$  is preferably Cl and ED is said dicarboxylic acid diester as internal  
20 electron donor, preferably a phthalic acid diester, and contains halogen from about 10% to about 60% more than the amount of halogen calculated on the basis of the amounts of magnesium and titanium present, assuming that all of the magnesium is in the form of said  $MgX_2$  and all of the titanium is in the form of said  $TiX_4$ , wherein X is a halogen.

25

38. A catalyst component according to claim 35, 36 or 37, **characterized** in that it shows a X-ray diffraction pattern with a lamellar thickness indicating a peak at  $17^\circ 2\theta$ , showing a clear position shift compared to normal amorphous  $MgCl_2$  which gives a height indicating peak at  $15^\circ 2\theta$ .

30

39. Process for the polymerization of olefins, **characterized** by the steps of

(A) preparing a catalyst component according to any of claims 1-38

35 (B) feeding to a polymerization reactor said catalyst component, as well as a cocatalyst, which has the formula (4)



wherein R is a C<sub>1</sub>-C<sub>10</sub> alkyl, preferably a C<sub>1</sub>-C<sub>4</sub> alkyl, most preferably ethyl, X is a halogen, preferably chlorine, p is an integer from 1 to (3r-1), preferably 2 or 3, most preferably 3, and r is 1 or 2, preferably 1, the molar ratio between said catalyst component and said cocatalyst, expressed as Al/Ti, preferably being 10-2000, more preferably 50-1000, most preferably 200-500,

optionally an external electron donor, which preferably is a silane, more preferably a C<sub>1</sub>-C<sub>12</sub> alkyl - C<sub>1</sub>-C<sub>12</sub> alkoxy silane, most preferably cyclohexyl methyl dimethoxy silane,

optionally a C<sub>4</sub>-C<sub>10</sub> hydrocarbon solvent, preferably pentane, hexane and/or heptane,

preferably a chain transfer agent, which is hydrogen, and

at least one olefin monomer, which preferably is propene,

(C) carrying out the polymerization of said olefin monomer in said polymerization reactor to give an olefin polymer (=homopolymer or copolymer) and

(D) recovering said olefin polymer.

40. Process according to claim 39, **characterized** in that said catalyst component is prepared by the process of any of claims 2 to 33.

41. Process for the polymerization of olefins, **characterized** by the steps of

(A) providing a solid olefin polymerization catalyst component which is essentially homogenous and comprises a magnesium dihalide, a titanium tetrahalide, and a dicarboxylic acid diester as internal electron donor ED in the following ratio (3):



wherein MgX<sub>2</sub> is said magnesium dihalide, TiX''<sub>4</sub> is said titanium tetrahalide, X and/or X'' is preferably Cl, and ED is said dicarboxylic acid diester as internal donor, preferably a phthalic acid diester, and contains halogen from about 10% to about 60% more than the amount of halogen calculated on the basis of the amounts of magnesium and titanium present, assuming that all of the magnesium is in the

form of said  $MgX_2$  and all of the titanium is in the form of said  $TiX_4$ , wherein X is a halogen.

- 5 (B) feeding to at least one polymerization reactor said catalyst component, as well as a cocatalyst which has the formula (4)



- 10 wherein R is a  $C_1$ - $C_{10}$  alkyl, preferably a  $C_1$ - $C_4$  alkyl, most preferably ethyl, X is a halogen, preferably chlorine, p is an integer from 1 to  $(3r-1)$ , preferably 2 or 3, most preferably 3, and r is 1 or 2, preferably 1, the molar ratio between said catalyst component and said cocatalyst, expressed as Al/Ti, preferably being 10-2000, more preferably 50-1000, most preferably 200-500,

15

optionally an external electron donor, which preferably is a silane, more preferably a  $C_1$ - $C_{12}$  alkyl -  $C_1$ - $C_{12}$  alkoxy silane, most preferably cyclohexyl methyl dimethoxy silane,

- 20 optionally a  $C_4$ - $C_{10}$  hydrocarbon solvent, preferably pentane, hexane and/or heptane,

preferably a chain transfer agent, which is hydrogen, and

25

at least one olefin monomer, which preferably is propylene,

(C) carrying out the polymerization of said olefin monomer in said polymerization reactor to give an olefin polymer (= homopolymer or copolymer) and

(D) recovering said olefin polymer.

## AMENDED CLAIMS

[received by the International Bureau on 5 January 2000 (05.01.00);  
original claim 1 amended; remaining claims unchanged (9 pages)]

1. A process for the preparation of an olefin polymerization catalyst component comprising a magnesium dihalide, a titanium tetrahalide, and a dicarboxylic acid diester as internal electron donor ED, **characterized** by the steps of:

5

(i) providing a magnesium compound (ab) containing an alkoxy moiety, selected from the group consisting of a magnesium dialkoxide, a complex containing a magnesium dihalide and an alcohol, and a complex containing a magnesium dihalide and a magnesium dialkoxide, and

10

(ii) reacting said magnesium compound (ab) with at least one dicarboxylic acid dihalide (c) which forms said dicarboxylic acid diester as internal donor ED and has the formula (1):

15



wherein each R'' is a similar or different C<sub>1</sub>-C<sub>20</sub> hydrocarbyl group or both R''s form together with the two unsaturated carbons of the formula a C<sub>5</sub>-C<sub>20</sub> aliphatic or aromatic ring, and X' is a halogen, to give an intermediate (abc),

20

(iii) reacting said intermediate (abc) with at least one titanium tetrahalide TiX''<sub>4</sub> (d) wherein X'' is a halogen,

25

(iv) recovering said catalyst component in crude form or recovering a precursor of said catalyst component, and

(v) optionally washing said crude catalyst component or said precursor, to give said catalyst component, and

30

by adding and reacting in connection with the above step (ii) or (iii) at least one reactive halogenated hydrocarbon (e) of the formula (2)



wherein R''' is an n-valent C<sub>1</sub>-C<sub>20</sub> hydrocarbyl group, X''' is a halogen and n is an integer selected from 1, 2, 3 and 4.

5

2. A process according to claim 1, **characterized** in that at least one, preferably all of steps (i) to (iii), are performed in solution, preferably by using one or several hydrocarbon solvents and optionally applying stirring and/or heat.

10 3. A process according to claim 2, **characterized** in that in step (iv), said catalyst component is recovered by precipitation.

4. A process according to claim 1, 2 or 3, **characterized** in that in said reactive halogenated hydrocarbon (e) of formula (2), R''' is a mono or bivalent C<sub>1</sub>-C<sub>10</sub>  
15 hydrocarbyl group, X''' is chlorine and n is 1 or 2, preferably that said hydrocarbyl halide (e) is a butyl chloride or (1,4)-dichlorobutane, most preferably that it is tertiary butyl chloride or (1,4)-dichlorobutane.

5. A process according to any preceding claim, **characterized** in that said  
20 reactive halogenated hydrocarbon (e) is added in an amount corresponding to a molar ratio Mg<sub>total added</sub>/(e) of between 1:0.2 and 1:20, preferably between about 1:1 and about 1:4.

6. A process according to any preceding claim, **characterized** in that said  
25 magnesium compound (ab) containing an alkoxy moiety is provided by reacting at least one magnesium compound precursor (a), selected from the group consisting of a dialkyl magnesium R<sub>2</sub>Mg, an alkyl magnesium alkoxide, wherein each R is a similar or different C<sub>1</sub>-C<sub>20</sub> alkyl, and a magnesium dihalide MgX<sub>2</sub>, wherein X is a halogen with at least one alcohol (b), selected from the group consisting of  
30 monohydric alcohols R'OH and polyhydric alcohols R'(OH)<sub>m</sub>, wherein R' is an 1-valent or, respectively, an m-valent C<sub>1</sub>-C<sub>20</sub> hydrocarbyl group and m is an integer selected from 2, 3, 4, 5 and 6, to give said magnesium compound (ab).

7. A process according to any preceding claim, **characterized** in that said  
35 magnesium compound precursor (a) is a dialkyl magnesium R<sub>2</sub>Mg, in which each R is a similar or different C<sub>4</sub>-C<sub>12</sub> alkyl group, preferably in which one R is a butyl group and the other R is an octyl group.

8. A process according to any preceding claim, **characterized** in that said magnesium compound precursor (a) is a magnesium dihalide, which is magnesium dichloride.
- 5 9. A process according to any preceding claim, **characterized** in that said magnesium compound (ab) is provided by reacting, in any order, a dialkyl magnesium  $R_2Mg$  and a magnesium dihalide  $MgX_2$  with at least one alcohol (b), selected from the consisting of monohydric alcohols  $R'OH$  and polyhydric alcohols  $R'(OH)_m$ , wherein  $R'$  is an 1-valent or, respectively, an m-valent  $C_1-C_{20}$  hydro-  
10 carbonyl group and m is an integer selected from 2, 3, 4, 5 and 6.
10. A process according to any preceding claim, **characterized** in that said alcohol (b) is a monohydric alcohol  $R'OH$  in which  $R'$  is a  $C_2-C_{16}$  alkyl group, preferably a  $C_4-C_{12}$  alkyl group, or most preferably that said alcohol (b) is 2-ethyl-1-hexanol.
- 15 11. A process according to any preceding claim, **characterized** in that said magnesium compound (a) is in step (i) reacted with said alcohol (b) which is said monohydric alcohol  $R'OH$ , in a molar ratio  $Mg/ROH$  of between 1:4 and 1:1, preferably between about 1:2.5 and about 1:1.5.
- 20 12. A process according to any preceding claim, **characterized** in that said alcohol (b) is a polyhydric alcohol  $R'(OH)_m$ , wherein  $R'$  is a di, tri or tetravalent  $C_2-C_{16}$  alkyl group and m is an integer selected from 2, 3 and 4, preferably a polyhydric alcohol selected from the group consisting of ethylene glycol, 2-butyl-2-ethyl-1,3-  
25 propanediol and glycerol.
13. A process according to any preceding claim, **characterized** in that in step (i), said magnesium compound precursor (a) is reacted with said alcohol (b) which is said polyhydric alcohol  $R'(OH)_m$  in a molar ratio  $Mg/R'(OH)_m$  of between 1:1 and  
30 1:0.25, preferably between about 1:0.8 and about 1:0.3.
14. A process according to any preceding claim, **characterized** in that in step (i), said magnesium compound precursor (a) is reacted with at least two of said alcohols (b), one of which is said monohydric alcohol  $R'OH$  and the other of which is said  
35 polyhydric alcohol  $R'(OH)_m$ .

15. A process according to any preceding claim, **characterized** in that in step (i), said magnesium compound precursor (a) is reacted with said at least one alcohol (b), under at least one of the following conditions:
- 5 - at raised temperature, preferably at about 30 °C to about 80 °C,
  - for a period of about 10 min to about 90 min, preferably about 30 min,
  - in the presence of a C<sub>5</sub>-C<sub>10</sub> hydrocarbon solvent, preferably heptane.
16. A process according to any preceding claim, **characterized** in that in said  
10 dicarboxylic acid dihalide (c) of the formula (1), both R''s form together with the two unsaturated carbons of said formula (1) a C<sub>5</sub>-C<sub>20</sub> aliphatic or a C<sub>6</sub>-C<sub>20</sub> aromatic ring, and X' is chlorine, preferably that said dicarboxylic acid dihalide (c) is phthaloyl dichloride.
- 15 17. A process according to any preceding claim, **characterized** in that in step (ii), said magnesium compound (ab) is reacted with said dicarboxylic acid dihalide (c) in a molar ratio Mg<sub>total added</sub>/(c) between 1:1 and 1:0.1, preferably between about 1:0.6 and about 1:0.25.
- 20 18. A process according to any preceding claim, **characterized** in that that in step (ii), said magnesium compound (ab) is reacted with said dicarboxylic acid dihalide (c), under at least one of the following conditions:
- adding said dicarboxylic acid dihalide (c) under room temperature and heating the obtained reaction mixture,
  - 25 - keeping the reactants together at raised temperature, preferably at about 30 °C to about 80 °C,
  - keeping the reactants together for a period of about 10 min to about 90 min, preferably about 30 min,
  - reacting the reactants in the presence of a C<sub>5</sub>-C<sub>10</sub> hydrocarbon solvent, pref-  
30 erably heptane.
19. A process according to claim 18, **characterized** in that after said magnesium compound (ab) has been reacted with said dicarboxylic acid dihalide (c), said C<sub>5</sub>-C<sub>10</sub> hydrocarbon solvent, preferably heptane, is removed by evaporation,  
35 preferably at about 100°C to about 110°C.
20. A process according to claim 19, **characterized** in that after said C<sub>5</sub>-C<sub>10</sub> hydrocarbon solvent, preferably said heptane, has been removed by evaporation,

said second intermediate (abc) is contacted with said reactive halogenated hydrocarbon (e), preferably for a period of about 10 min to about 90 min, preferably about 30 min.

- 5 21. A process according to claim 20, **characterized** in that after said intermediate (abc) has been contacted with said reactive halogenated hydrocarbon (e), a dissolving C<sub>5</sub>-C<sub>10</sub> hydrocarbon, preferably toluene, is added, most preferably in a molar ratio  $Mg_{\text{total added}}/\text{toluene}$  of between about 1:2 and about 1:10.
- 10 22. A process according to any preceding claim, **characterized** in that said titanium tetrahalide (d) is titanium tetrachloride.
23. A process according to any preceding claim, **characterized** in that in step (iii), said intermediate (abc) is reacted with said titanium tetrahalide (d) in a molar ratio  
15  $Mg_{\text{total added}}/(d)$  between 1:100 and 1:1, preferably between about 1:50 and about 1:5, most preferably about 1:10.
24. A process according to any preceding claim, **characterized** in that, in step (iii), said intermediate (abc), preferably a solution thereof, is added slowly,  
20 preferably dropwise, to said titanium tetrahalide (d), which preferably is hot (e.g. 110 °C), to form a solution of said catalyst component.
25. A process according to claim 21 and 24, **characterized** in that said toluene solution of said intermediate (abc) is added dropwise to said titanium tetrahalide (d)  
25 at 110 °C.
26. A process according to claim 25, **characterized** in that of said intermediate (abc) is reacted with said titanium tetrahalide (d) at 110 °C for about 5 min to about  
30 20 min, preferably for about 10 min.
27. A process according to any preceding claim, **characterized** in that in step (iv), said catalyst component in crude form or a precursor thereof is recovered by cooling a solution of said catalyst component, preferably said toluene solution of said catalyst component, for the precipitation of said crude catalyst component or said  
35 precursor thereof and preferably allowing it to settle.
28. A process according to claim 27, **characterized** in that immediately before said precipitation, a C<sub>5</sub>-C<sub>10</sub> hydrocarbon solvent, preferably toluene, most preferably

toluene in a molar ratio  $Mg_{\text{total added}}/\text{toluene}$  of about 1:10 to about 1:100, is added to said catalyst component solution.

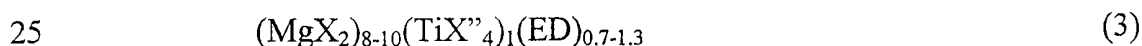
29. A process according to claim 27 or 28, **characterized** in that after said crude catalyst component or said precursor thereof has settled, the supernatant liquid is removed e.g. by decanting or siphoning.

30. A process according to any preceding claim, **characterized** in that in step (v), said recovered crude catalyst component or said precursor thereof is washed with toluene, preferably with hot (e.g. 90 °C) toluene.

31. A process according to any preceding claim, **characterized** in that in step (v), said recovered crude catalyst component or said precursor thereof is washed with heptane, preferably with hot (e.g. 90 °C) heptane.

32. A process according to any preceding claim, **characterized** in that in step (v), said recovered crude catalyst component or precursor thereof is washed with pentane.

33. A process according to any preceding claim, **characterized** in that in step (v) said recovered crude catalyst component or precursor thereof is washed to give the following ratio of said magnesium dihalide, said titanium tetrahalide, and said dicarboxylic acid diester as internal electron donor ED (3):



wherein  $MgX_2$  is said magnesium dihalide,  $TiX''_4$  is said titanium tetrahalide and ED is said dicarboxylic acid diester as internal electron donor, preferably a phthalic acid diester, whereby said recovered catalyst component is preferably washed first with toluene, more preferably hot (e.g. 90 °C) toluene, then at least twice with hot (90°) heptane, and finally with pentane.

34. A process according to any preceding claim, **characterized** in that the washed catalyst component is dried, preferably by evaporation.

35. An olefin polymerization catalyst component comprising a magnesium dihalide, a titanium tetrahalide, and a dicarboxylic acid diester as internal electron

donor ED, **characterized** in that it has been prepared according to the process of any preceding claim.

36. A catalyst component according to claim 34, **characterized** in that it contains  
5 halogen from about 10% to about 60% more than the amount of halogen calculated on the basis of the amounts of magnesium and titanium present, assuming that all of the magnesium is in the form of said  $MgX_2$  and all of the titanium is in the form of said  $TiX_4$ , wherein X is a halogen.

10 37. A solid olefin polymerization catalyst component comprising a magnesium dihalide, a titanium tetrahalide, and a dicarboxylic acid diester as internal donor ED, **characterized** in that it is essentially homogenous and has the following ratio of said magnesium dihalide, said titanium tetrahalide, and said dicarboxylic acid diester as internal electron donor ED (3):

15



wherein  $MgX_2$  is said magnesium dihalide,  $TiX''_4$  is said titanium tetrahalide, X and/or  $X''$  is preferably Cl and ED is said dicarboxylic acid diester as internal  
20 electron donor, preferably a phthalic acid diester, and contains halogen from about 10% to about 60% more than the amount of halogen calculated on the basis of the amounts of magnesium and titanium present, assuming that all of the magnesium is in the form of said  $MgX_2$  and all of the titanium is in the form of said  $TiX_4$ , wherein X is a halogen.

25

38. A catalyst component according to claim 35, 36 or 37, **characterized** in that it shows a X-ray diffraction pattern with a lamellar thickness indicating a peak at  $17^\circ 2\theta$ , showing a clear position shift compared to normal amorphous  $MgCl_2$  which gives a height indicating peak at  $15^\circ 2\theta$ .

30

39. Process for the polymerization of olefins, **characterized** by the steps of

(A) preparing a catalyst component according to any of claims 1-38

35 (B) feeding to a polymerization reactor said catalyst component, as well as a cocatalyst, which has the formula (4)



wherein R is a C<sub>1</sub>-C<sub>10</sub> alkyl, preferably a C<sub>1</sub>-C<sub>4</sub> alkyl, most preferably ethyl, X is a halogen, preferably chlorine, p is an integer from 1 to (3r-1), preferably 2 or 3, most preferably 3, and r is 1 or 2, preferably 1, the molar ratio between said catalyst component and said cocatalyst, expressed as Al/Ti, preferably being 10-2000, more preferably 50-1000, most preferably 200-500,

optionally an external electron donor, which preferably is a silane, more preferably a C<sub>1</sub>-C<sub>12</sub> alkyl - C<sub>1</sub>-C<sub>12</sub> alkoxy silane, most preferably cyclohexyl methyl dimethoxy silane,

optionally a C<sub>4</sub>-C<sub>10</sub> hydrocarbon solvent, preferably pentane, hexane and/or heptane,

preferably a chain transfer agent, which is hydrogen, and

at least one olefin monomer, which preferably is propene,

(C) carrying out the polymerization of said olefin monomer in said polymerization reactor to give an olefin polymer (=homopolymer or copolymer) and

(D) recovering said olefin polymer.

40. Process according to claim 39, characterized in that said catalyst component is prepared by the process of any of claims 2 to 33.

41. Process for the polymerization of olefins, characterized by the steps of

(A) providing a solid olefin polymerization catalyst component which is essentially homogenous and comprises a magnesium dihalide, a titanium tetrahalide, and a dicarboxylic acid diester as internal electron donor ED in the following ratio (3):



wherein MgX<sub>2</sub> is said magnesium dihalide, TiX''<sub>4</sub> is said titanium tetrahalide, X and/or X'' is preferably Cl, and ED is said dicarboxylic acid diester as internal donor, preferably a phthalic acid diester, and contains halogen from about 10% to about 60% more than the amount of halogen calculated on the basis of the amounts of magnesium and titanium present, assuming that all of the magnesium is in the

form of said  $MgX_2$  and all of the titanium is in the form of said  $TiX_4$ , wherein X is a halogen.

- 5 (B) feeding to at least one polymerization reactor said catalyst component, as well as a cocatalyst which has the formula (4)



- 10 wherein R is a  $C_1$ - $C_{10}$  alkyl, preferably a  $C_1$ - $C_4$  alkyl, most preferably ethyl, X is a halogen, preferably chlorine, p is an integer from 1 to  $(3r-1)$ , preferably 2 or 3, most preferably 3, and r is 1 or 2, preferably 1, the molar ratio between said catalyst component and said cocatalyst, expressed as Al/Ti, preferably being 10-2000, more preferably 50-1000, most preferably 200-500,

15

optionally an external electron donor, which preferably is a silane, more preferably a  $C_1$ - $C_{12}$  alkyl -  $C_1$ - $C_{12}$  alkoxy silane, most preferably cyclohexyl methyl dimethoxy silane,

- 20 optionally a  $C_4$ - $C_{10}$  hydrocarbon solvent, preferably pentane, hexane and/or heptane,

preferably a chain transfer agent, which is hydrogen, and

- 25 at least one olefin monomer, which preferably is propylene,

(C) carrying out the polymerization of said olefin monomer in said polymerization reactor to give an olefin polymer (= homopolymer or copolymer) and

(D) recovering said olefin polymer.

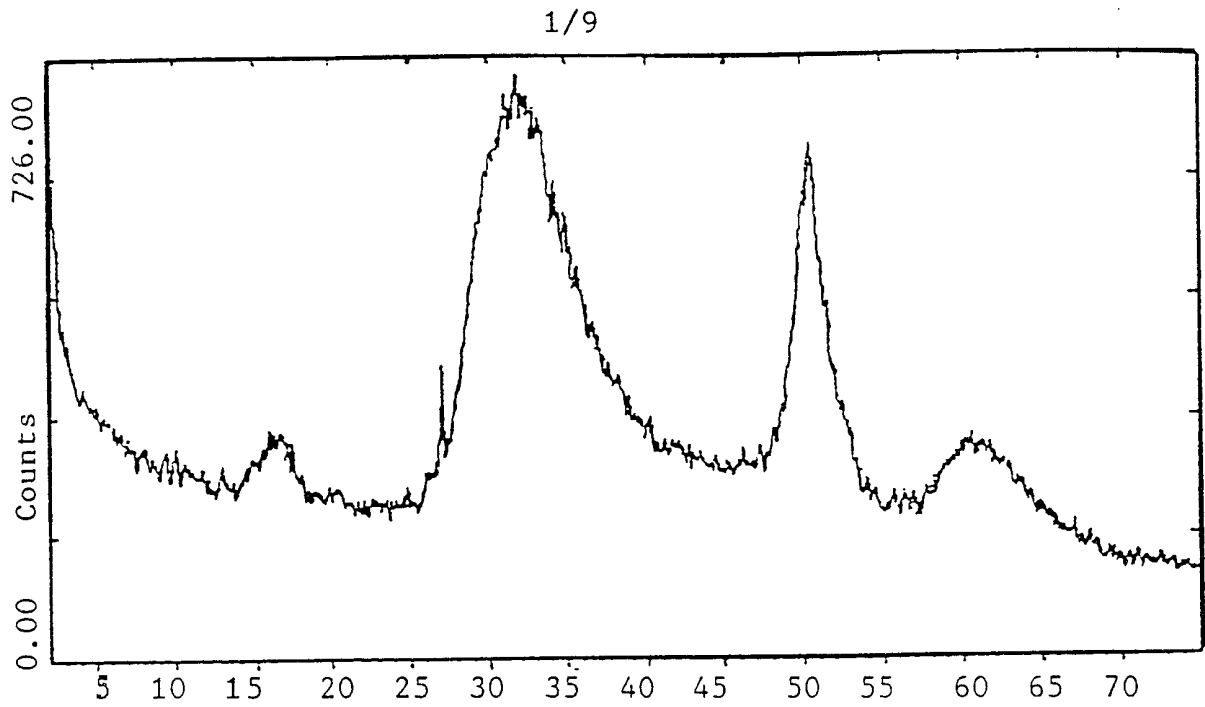


Figure 1

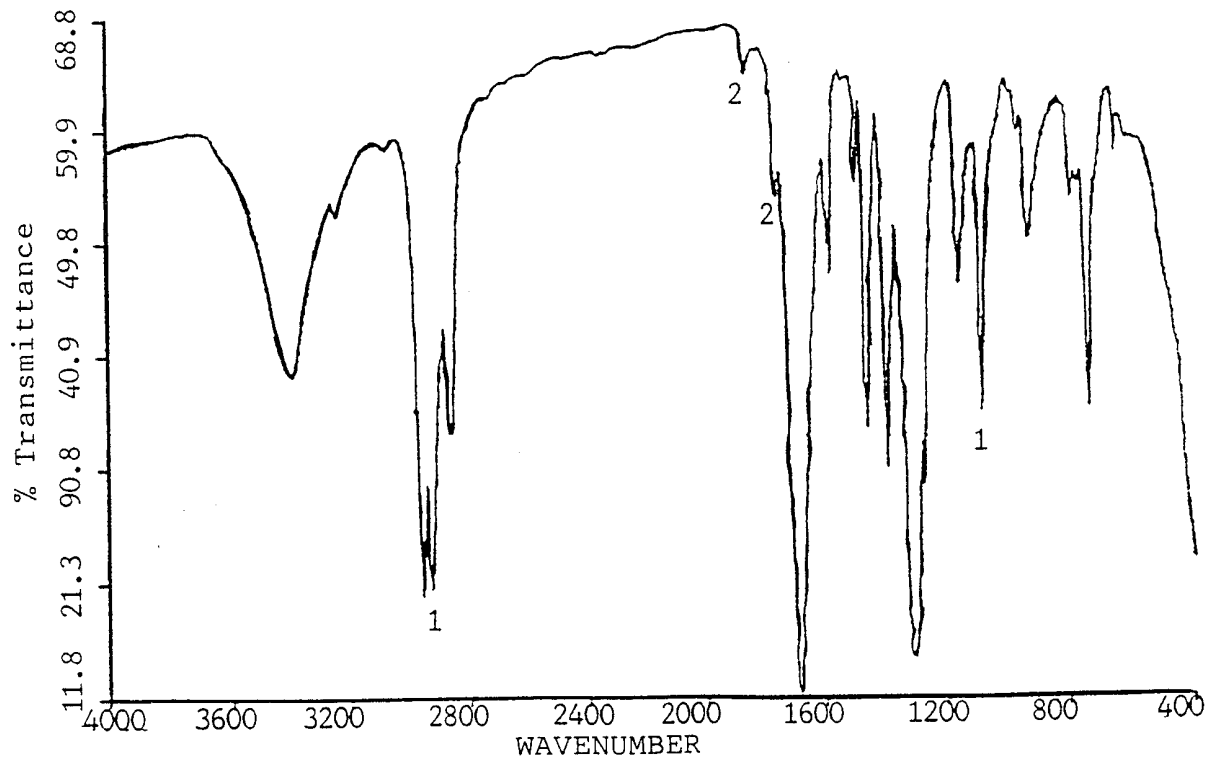


Figure 2

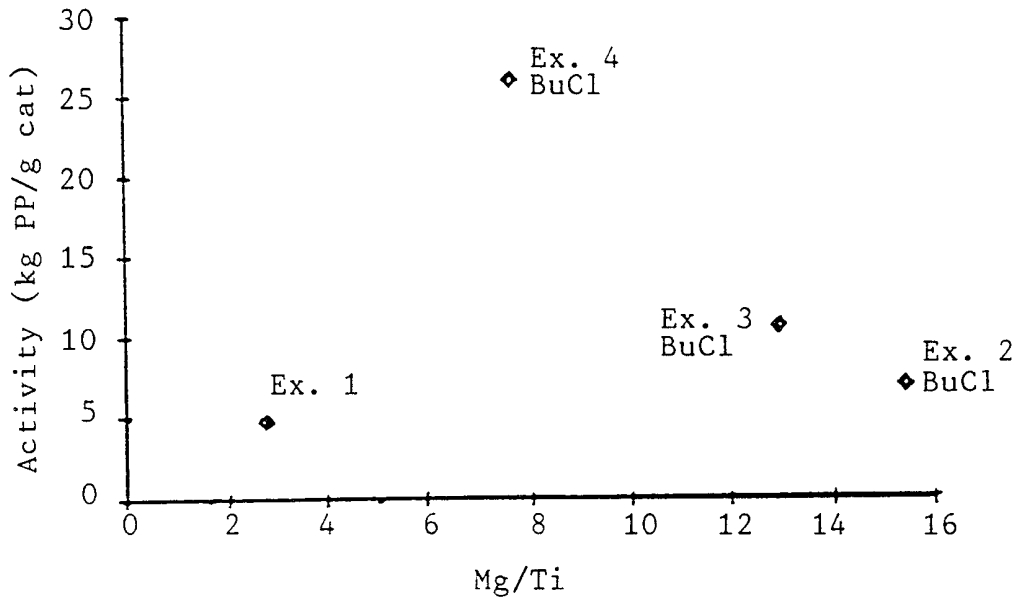


Figure 3

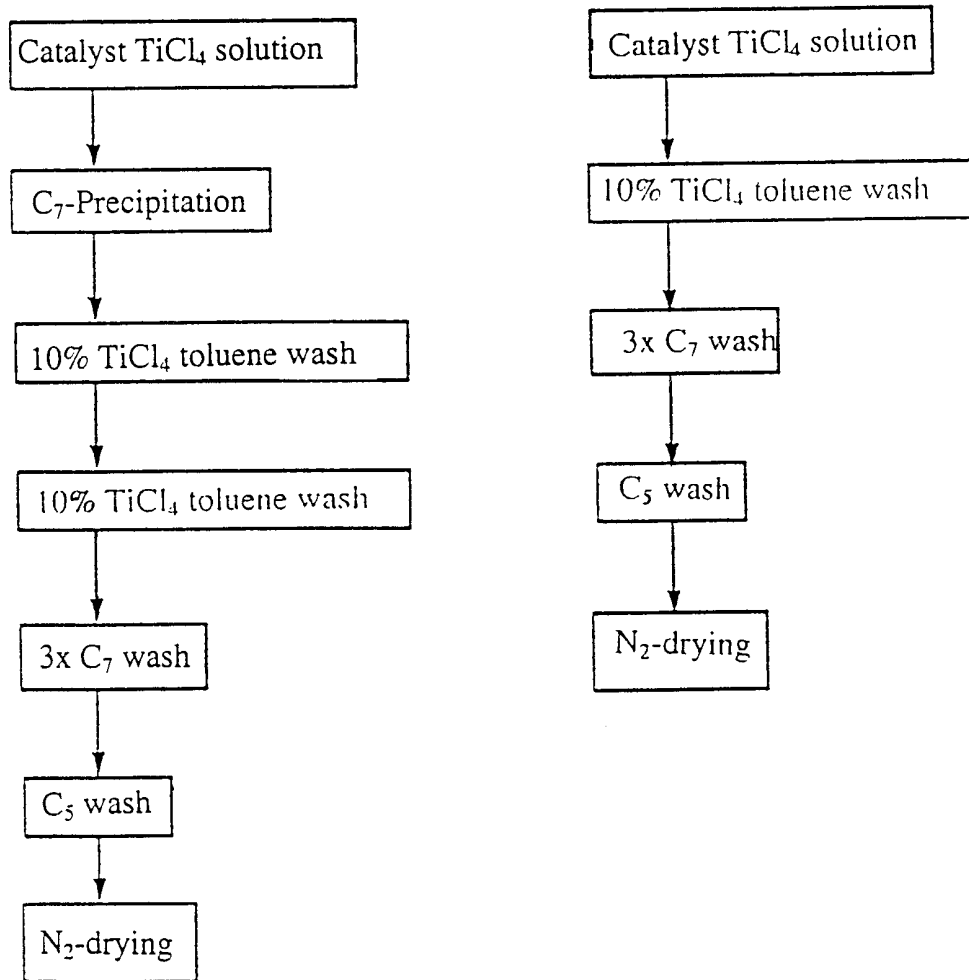


Figure 4

09-Sep-1997

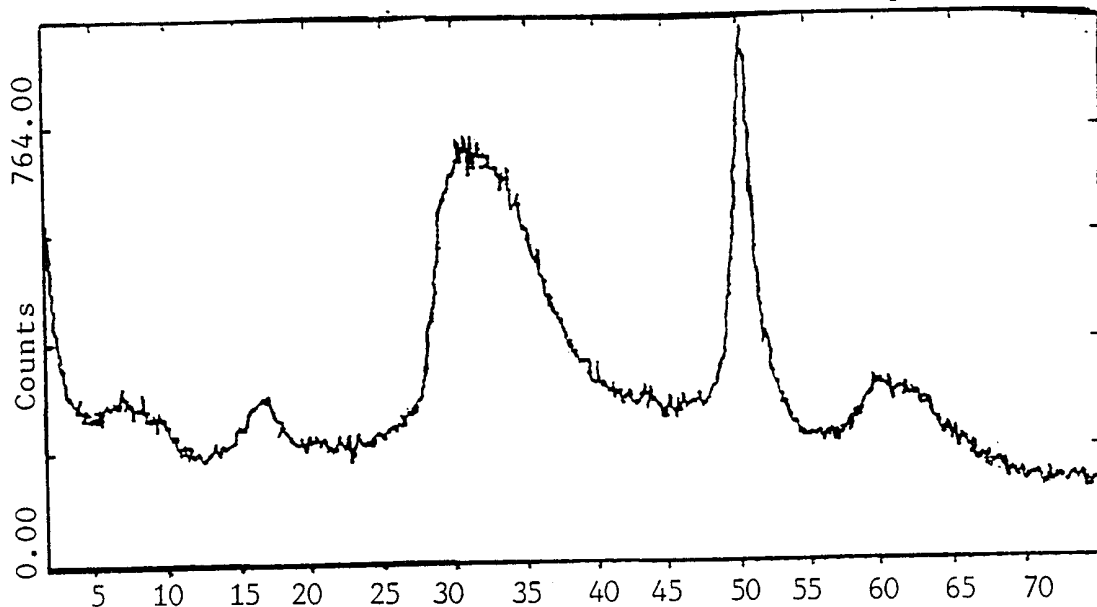


Figure 5

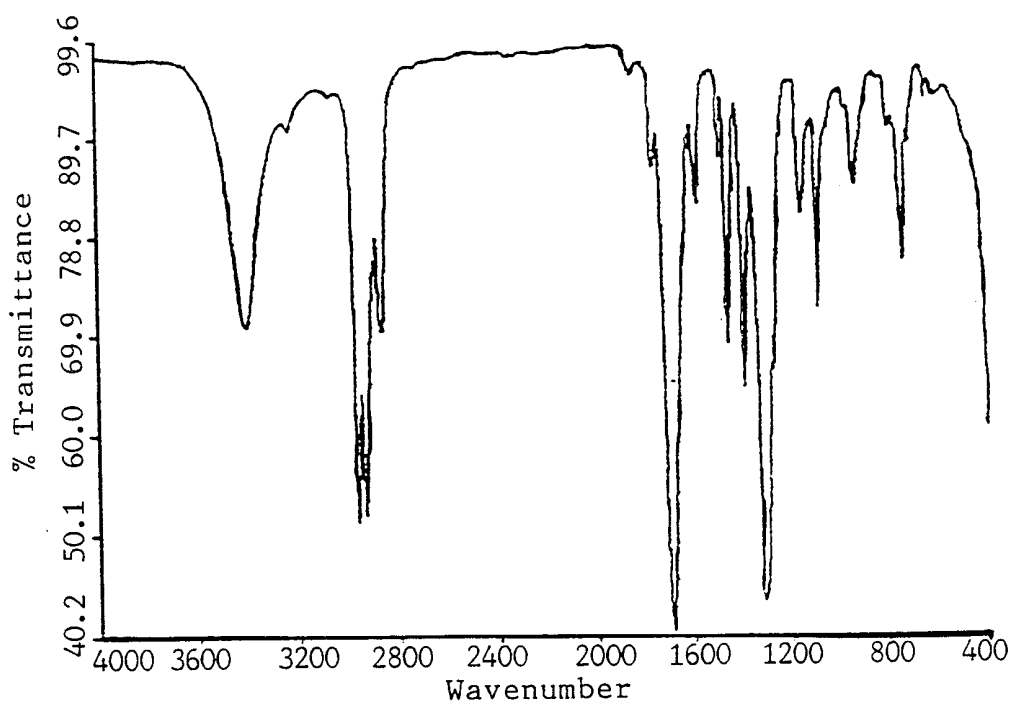


Figure 6

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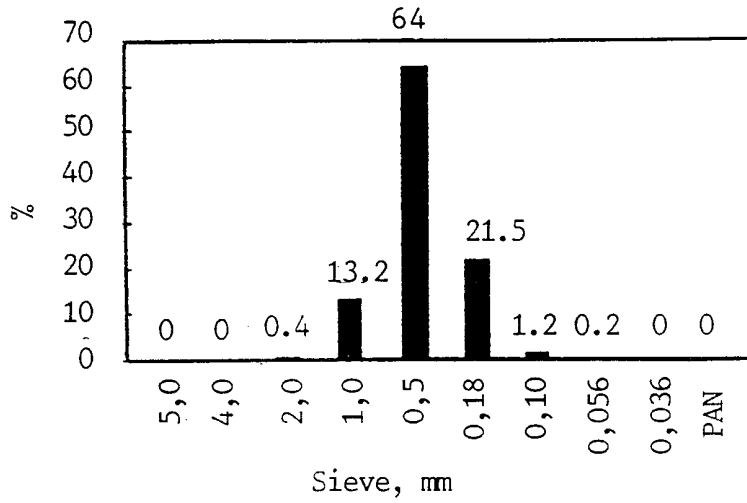


Figure 7

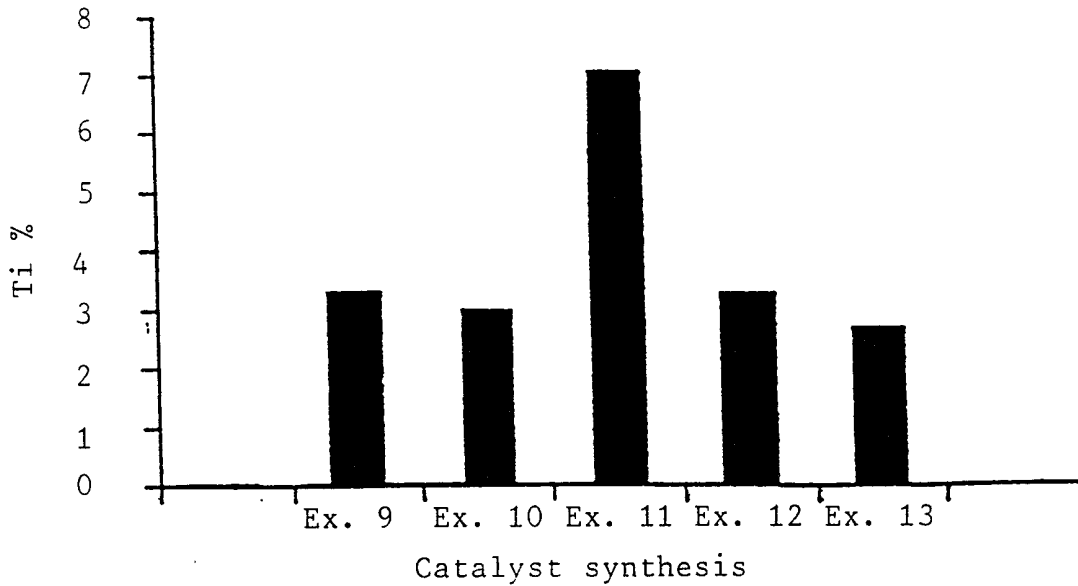


Figure 8

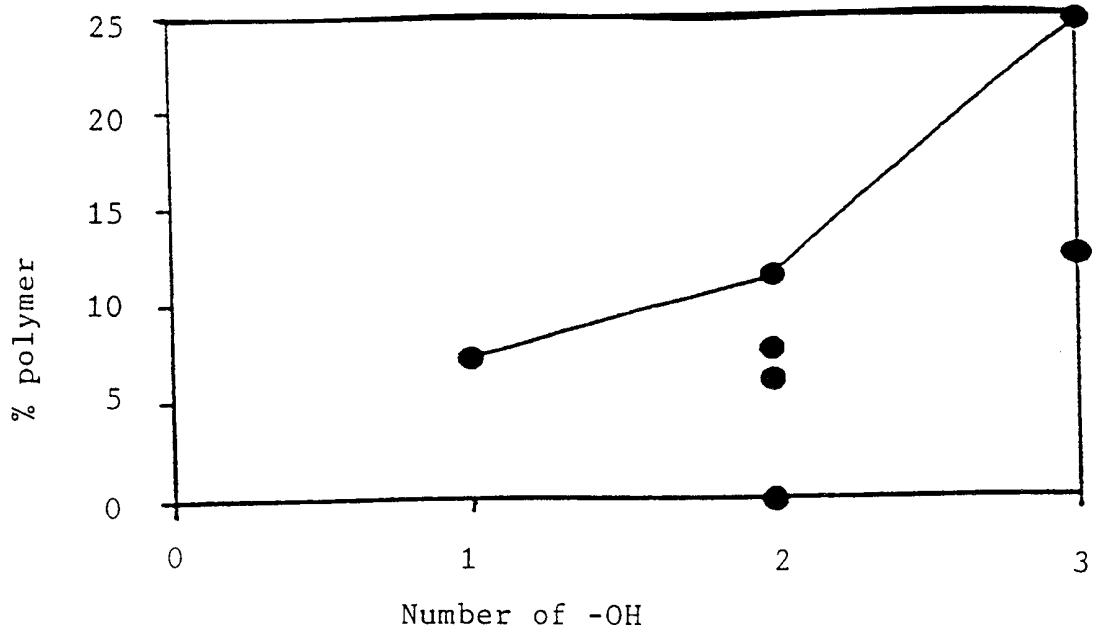


Figure 9

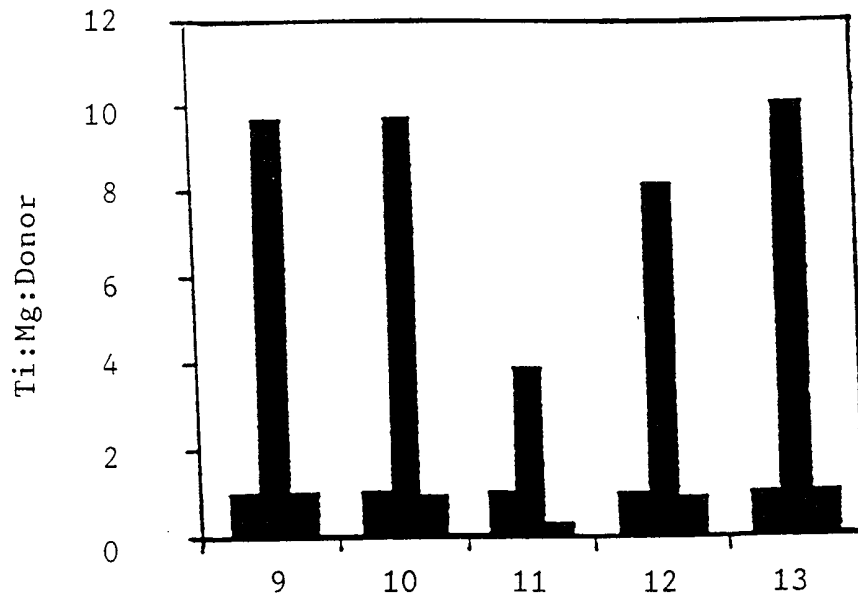


Figure 10

Example

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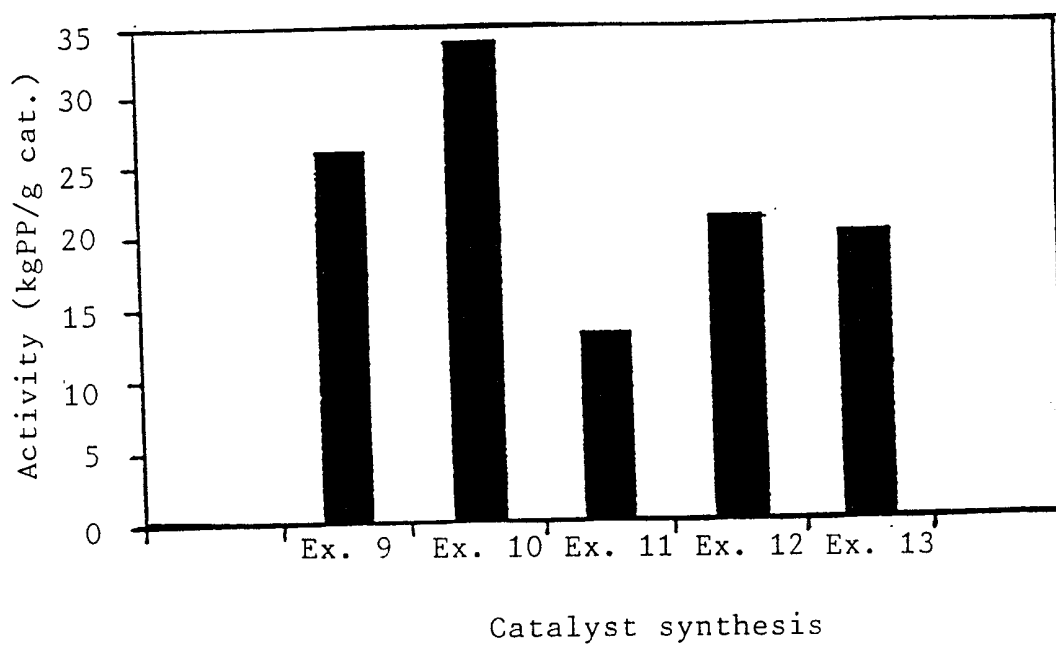


Figure 11

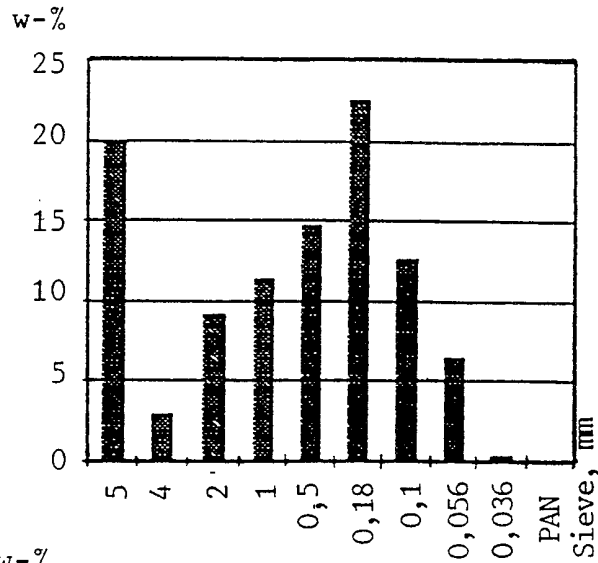


Figure 12a

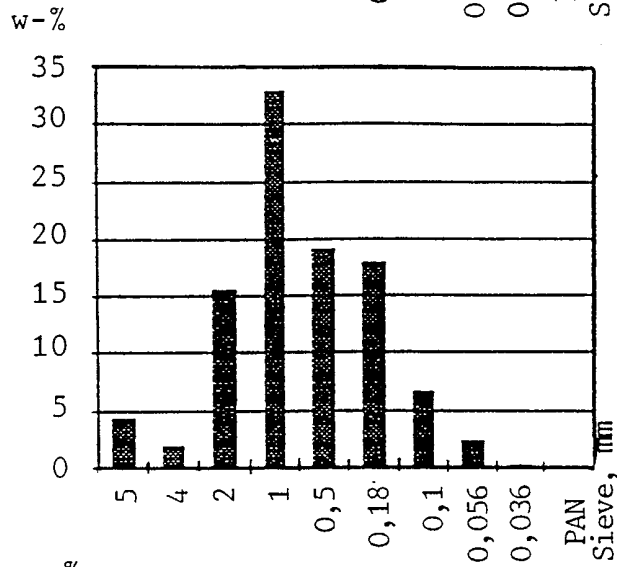


Figure 12b

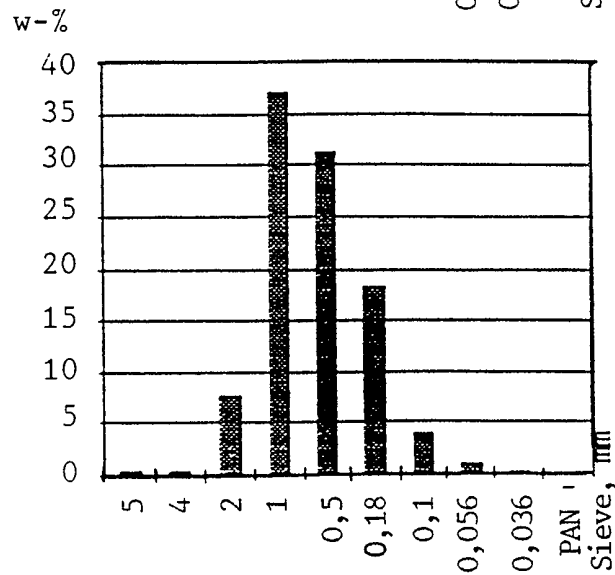


Figure 12c

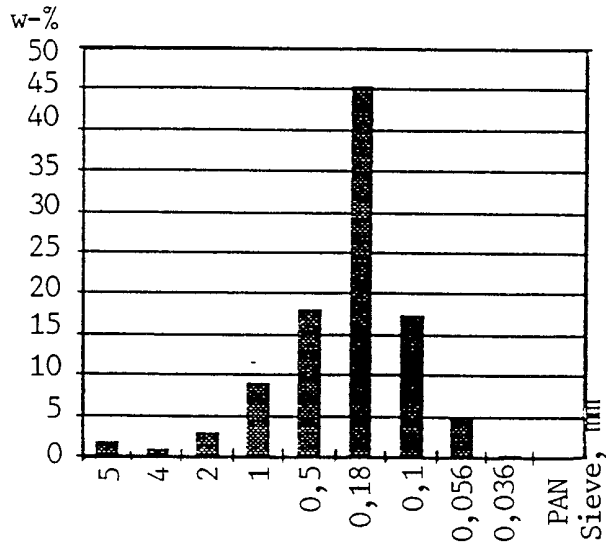


Figure 12d

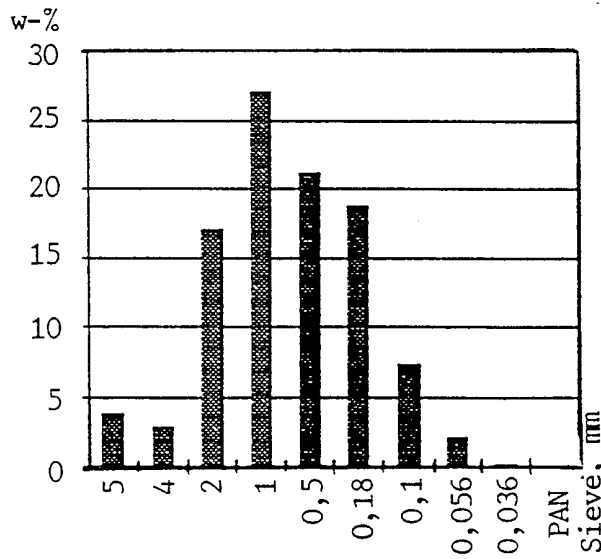


Figure 12e

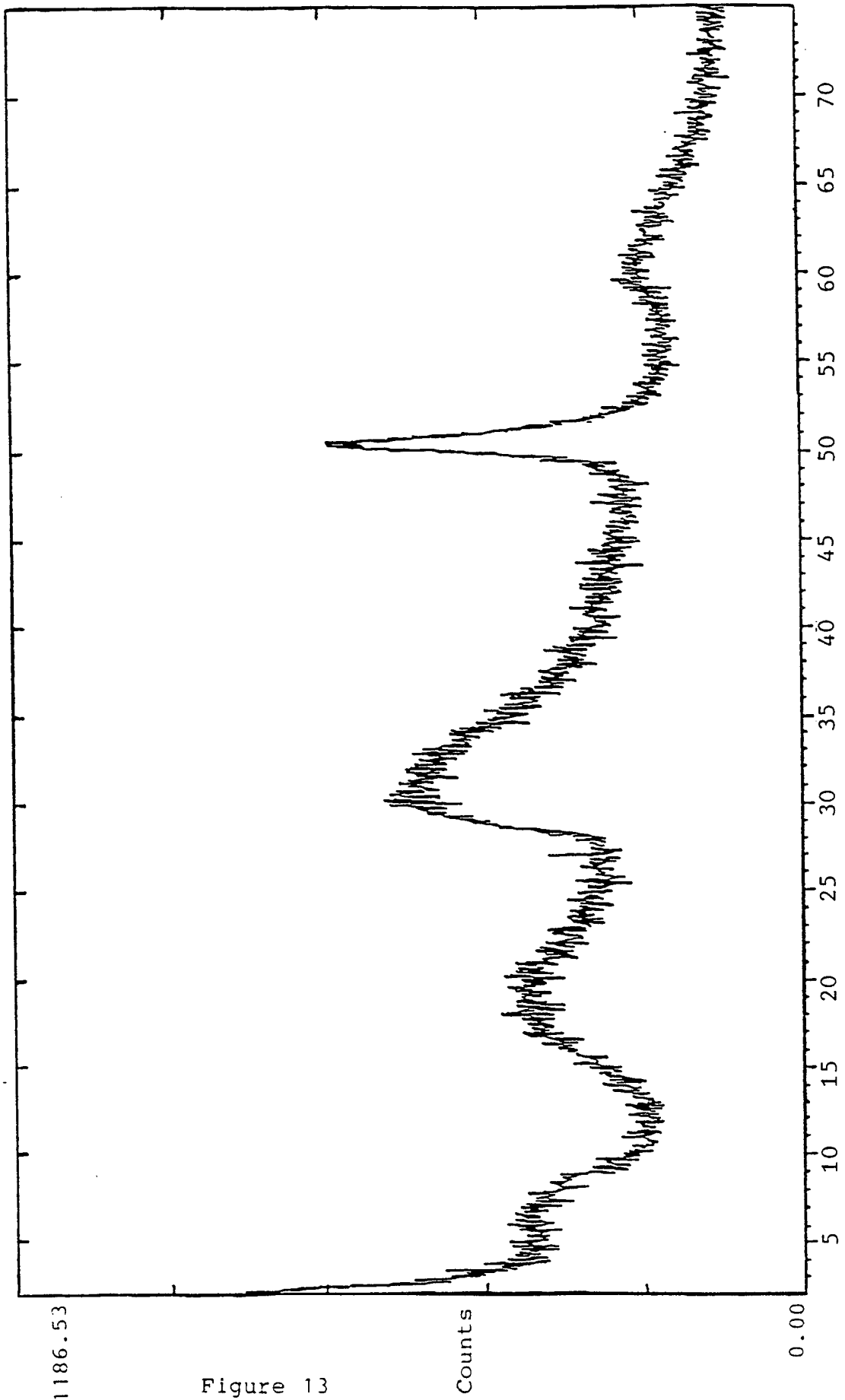


Figure 13

INTERNATIONAL SEARCH REPORT

International Application No  
PC, FI 99/00657

A. CLASSIFICATION OF SUBJECT MATTER  
IPC 7 C08F110/06 C08F4/651 C08F4/654

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)  
IPC 7 C08F

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category ° | Citation of document, with indication, where appropriate, of the relevant passages   | Relevant to claim No.  |
|------------|--|--|
| X          | EP 0 173 472 A (TOA NENRYO KOGYO KK)<br>5 March 1986 (1986-03-05)  | 1-4,6,7,<br>10,11,<br>16,17,<br>22,23,<br>27,29,<br>30,34,<br>35,39,40 |
| A          | examples 1,3<br>example 42; table IV<br>comparative experiment 1<br>applied example 42; table VI<br>page 4, line 7 - line 15<br>page 7, line 10 - line 15<br>page 7, line 29 - line 35<br>page 8, line 13 -page 9, line 20<br>claims 1,5; examples 1,3 | 12,15,<br>18,32  |
|            | ---  | -/--   |

Further documents are listed in the continuation of box C.

Patent family members are listed in annex.

° Special categories of cited documents :

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"E" earlier document but published on or after the international filing date  
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"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone  
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art.  
"&" document member of the same patent family

Date of the actual completion of the international search

17 November 1999

Date of mailing of the international search report

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## INTERNATIONAL SEARCH REPORT

International Application No

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## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

| Category | Citation of document, with indication, where appropriate, of the relevant passages            | Relevant to claim No. |
|----------|---|-----------------------|
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| A        | US 4 804 648 A (JOB ROBERT C)<br>14 February 1989 (1989-02-14)<br>example 1; table 1<br>----- | 1                     |

## INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/FI 99/00657

| Patent document<br>cited in search report | Publication<br>date | Patent family<br>member(s) | Publication<br>date |
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