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Polymerization catalyst activators, method of preparing and their use in polymerization processes

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(54) Title: POLYMERIZATION CATALYST ACTIVATORS, METHOD OF PREPARING AND THEIR USE IN POLYMERIZATION PROCESSES

(57) Abstract: New polymerization catalyst activators are disclosed which include a heterocyclic compound, which may or may not be substituted, and an aluminium alkyl or an aluminosilane. Supported activators of the invention include the heterocyclic compound, combined with an alkyaluminum or aluminosilane, and a support material, preferably a silica support material. Also disclosed are methods for preparing these catalyst activators and polymerization processes utilizing same.

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**POLYMERIZATION CATALYST ACTIVATORS, METHOD OF PREPARING, AND  
THEIR USE IN POLYMERIZATION PROCESSES**

**FIELD OF THE INVENTION**

5   **[0001]**       The present invention relates to polymerization catalyst activator compounds, to methods of making these activator compounds, to polymerization catalyst systems containing these activator compounds, and to polymerization processes utilizing the same. More specifically the activators of the invention include a heterocyclic compound, which may or may not be substituted, and an aluminum alkyl or an aluminoxane. Supported activators of the invention include a heterocyclic compound, which may or may not be substituted, combined with an alkylaluminum or aluminoxane, and a support material, preferably a silica support material.

**BACKGROUND OF THE INVENTION**

15   **[0002]**       Polymerization catalyst compounds are typically combined with an activator (or co-catalyst) to yield compositions having a vacant coordination site that will coordinate, insert, and polymerize olefins. Metallocene polymerization catalysts are typically activated with aluminoxanes which are generally oligomeric compounds containing -Al(R)-O- subunits, where R is an alkyl group. The most common aluminoxane activator is methylaluminoxane (MAO), produced by the hydrolysis of trimethylaluminum (TMA). MAO, however, is expensive to utilize because it must be present in great excess relative to the metallocene and because of the high cost of TMA. In addition, MAO tends to be unstable as it precipitates out of solution over time.

25   **[0003]**       In addition, metallocene polymerization catalyst systems, utilized in industrial slurry or gas phases processes, are typically immobilized on a carrier or support, for example silica or alumina. Metallocenes are supported to enhance the morphology of the forming polymeric particles such that they achieve a shape and density that improves reactor operability and ease of handling. Metallocene catalysts, however, typically exhibit lower activity when supported when compared to the corresponding non-supported catalyst systems.

30   **[0004]**       Alternative activators for metallocenes and other single-site polymerization catalysts have been discovered in recent years. For example, perfluorophenyl aluminum and borane complexes containing one anionic nitrogen containing group may activate metallocenes. For example, *R. E. LaPointe, G.R. Roof, K. A. Abboud, J. Klosin*, 122 J. AM. CHEM. SOC. 9560-

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9561 (2000), and WO 01/23442 A1 report the synthesis of  $(C_6F_5)_3Al(imidazole)Al(C_6F_5)_3[HNR'R']$ . In addition, G. Kehr, R. Fröhlich, B. Wibbeling, G. Erker, 6(2) CHEM. EUR. J. 258-266 (2000) report the synthesis of  $(N-Pyrrolyl)B(C_6F_5)_2$ .

5 U.S. Patent Nos. 6,147,173 and 6,211,105 disclose a polymerization process and polymerization catalyst where the catalyst includes an activator complex having a Group 13 element and at least one halogenated, nitrogen-containing aromatic group ligand.

10 In light of the high cost and low stability of MAO and of the reduced activity when metallocenes are supported, there is a need in the art for new inexpensive, stable and supportable polymerization catalyst activator compounds. There is also a need in the art for methods for preparing these activator compounds, polymerization catalyst systems including these activator compounds and for polymerization processes utilizing the same.

15 The discussion of documents, acts, materials, devices, articles and the like is included in this specification solely for the purpose of providing a context for the present invention. It is not suggested or represented that any or all of these matters formed part of the prior art base or were common general knowledge in the field relevant to the present invention as it existed  
20 before the priority date of each claim of this application.

Throughout the description and the claims of this specification the word "comprise" and variations of the word, such as "comprising" and "comprises" is not intended to exclude other additives, components, integers or steps.

25

#### **SUMMARY OF THE INVENTION**

The activator compounds of the invention, in one embodiment, include a heterocyclic compound, which may or may not be substituted, utilized in combination with an alkylaluminum or aluminoxane and optionally a support  
30 material, preferably silica.

In another embodiment, the activator of the invention includes a heterocyclic compound having one or more heteroatoms selected from Group 15 or 16, preferably the heteroatom(s) is nitrogen, oxygen, or sulphur. The heterocyclic compounds may be unsubstituted, or one or more positions may be substituted. In a preferred embodiment, one or more positions on the heterocyclic compound is substituted with a halogen atom or a halogen containing group, where the halogen is chlorine, bromine or fluorine, preferably bromine or fluorine, most preferably fluorine.

In other embodiments, the invention provides for methods of preparing these activator compositions, for utilizing the activators in olefin(s) polymerization processes, and for polymers produced therefrom.

In one aspect, the present invention provides a catalyst system comprising a metallocene polymerization catalyst, and an activator wherein the activator comprises a heterocyclic compound wherein the heterocyclic compound is selected from the group consisting of pyrroles, imidazoles, pyrazoles, pyrrolines, pyrroles, 3-pentafluorophenyl pyrrole, 4,5,6,7-tetrafluoroindole, 3,4-difluoropyrroles, and combinations thereof; in combination with an aluminium containing compound; wherein the aluminium containing compound is an alumoxane or an alkylaluminum compound represented by the formula  $AlR_3$ , wherein each R is independently a substituted or unsubstituted alkyl group, and wherein the catalyst system further comprises a support material.

#### **DETAILED DESCRIPTION**

The polymerization catalyst activator of the invention includes a heterocyclic compound, which may be unsubstituted or substituted, utilized in combination with an alkylaluminum or an aluminoxane, and an optional support material.

For the purposes of this patent specification, term "activator" is used interchangeable with the term "co-catalyst," the term "catalyst" refers to a metal compound

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that when combined with an activator polymerizes olefins, and the term "catalyst system" refers to the combination of a catalyst, an activator, and an optional support material.

[0012] In one embodiment, the ring of the heterocyclic compound contains at least one atom selected from Group 15 or 16 of the Period Table of the Elements. More preferably the  
5 ring of the heterocyclic compound includes at least one nitrogen, oxygen, and/or sulfur atom, and more preferably includes at least one nitrogen atom. Preferably, the heterocyclic compound includes 4 or more ring members and more preferably 5 or more ring members.

[0013] The heterocyclic compound may be unsubstituted or substituted with one or a combination of substituent groups. Examples of suitably substituents include hydrogen,  
10 halogen, alkyl, alkenyl or alkynyl radicals, cycloalkyl radicals, aryl radicals, aryl substituted alkyl radicals, acyl radicals, aroyl radicals, alkoxy radicals, aryloxy radicals, alkylthio radicals, dialkylamino radicals, alkoxycarbonyl radicals, aryloxy carbonyl radicals, carbamoyl radicals, alkyl- or dialkyl- carbamoyl radicals, acyloxy radicals, acylamino radicals, aroylamino radicals, straight, branched or cyclic, alkylene radicals, or any combination thereof. The substituents  
15 groups may also be substituted with halogens, particularly fluorine or bromine, or heteroatoms or the like.

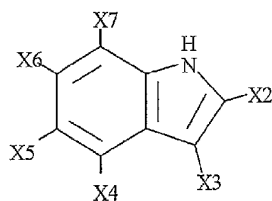
[0014] Non-limiting examples of substituents include methyl, ethyl, propyl, butyl, pentyl, hexyl, cyclopentyl, cyclohexyl, benzyl or phenyl groups and the like, including all their isomers, for example tertiary butyl, isopropyl, and the like. Other examples of substituents  
20 include fluoromethyl, fluoroethyl, difluoroethyl, iodopropyl, bromohexyl or chlorobenzyl.

[0015] In one embodiment, the heterocyclic compound is unsubstituted. In another embodiment one or more positions on the heterocyclic compound is substituted with a halogen atom or a halogen atom containing group, for example a halogenated aryl group. Preferably the halogen is chlorine, bromine or fluorine, more preferably fluorine or bromine and even more  
25 preferably the halogen is fluorine.

[0016] Non-limiting examples of heterocyclic compounds utilized in the activator of the invention include substituted and unsubstituted pyrroles, imidazoles, pyrazoles, pyrrolines, pyrrolidines, purines, carbazoles, and indoles, phenyl indoles, 2,5, dimethyl pyrroles, 3-pentafluorophenyl pyrrole, 4,5,6,7 tetrafluoroindole or 3,4 difluoropyrroles.

30 [0017] In a preferred embodiment, the heterocyclic compound is an indole represented by Formula (I).

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Formula (I)

**[0018]** In Formula I, the indole includes substituent groups X2-X7. Each X2-X7 is independently selected from hydrogen, halogen, preferably chlorine, bromine or fluorine, more preferably bromine or fluorine and most preferably fluorine, an alkyl group, an aryl group, an alkoxide group, an aryloxy group or an alkyl substituted aryl group wherein the groups may be halogenated or partially halogenated, preferably containing a fluorine atom and/or a bromine atom. In one embodiment, the indole is not perhalogenated. Preferably, Each X2-X7 is independently hydrogen, halogen, an alkyl group, a halogenated or partially halogenated alkyl group, an aryl group, a halogenated or partially halogenated aryl group, an aryl substituted alkyl group or a halogenated or partially halogenated aryl substituted alkyl group. Preferably the halogen is chlorine, bromine or fluorine, more preferably bromine or fluorine, and most preferably fluorine. In another embodiment, each of X2-X7 are independently hydrogen or halogen, preferably bromine or fluorine, more preferably fluorine. In another embodiment each of X2-X7 are independently an alkyl group, a halogenated or partially halogenated alkyl group, an aryl group, or a halogenated or partially halogenated aryl group.

**[0019]** In one embodiment, the heterocyclic compound described above are combined with an alkyl aluminum or an alumoxane to yield an activator compound which upon reaction with a catalyst precursor compound, for example a metallocene, produces an active polymerization catalyst.

**[0020]** In one embodiment, the heterocyclic compounds described above are utilized in combination with an alkylaluminum represented by Formula (II).



Formula (II)

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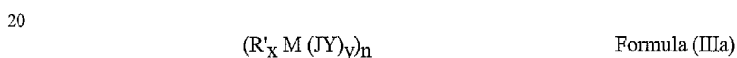
wherein each R is independently a substituted or unsubstituted alkyl group and/or a substituted or unsubstituted aryl group. Preferably R is an alkyl group containing 1 to 30 carbon atoms.

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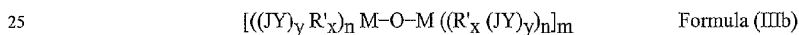
**[0021]** Non-limiting examples of alkylaluminums include trimethylaluminum, triethylaluminum, triisobutylaluminum, tri-n-hexylaluminum, tri-n-octylaluminum, tri-isooctylaluminum, triphenylaluminum, and combinations thereof.

**[0022]** In another embodiment, the heterocyclic compounds described above are utilized with an alumoxanes which are generally oligomeric compounds containing -Al(R)-O- or -Al(R)<sub>2</sub>-O- subunits, where R is an alkyl group. Examples of alumoxanes include methylalumoxane (MAO), modified methylalumoxane (MMAO), ethylalumoxane, isobutylalumoxane, tetraethyldialumoxane and di-isobutylalumoxane. Alumoxanes may be produced by the hydrolysis of the respective trialkylaluminum compound. MMAO may be produced by the hydrolysis of trimethylaluminum and a higher trialkylaluminum such as triisobutylaluminum. There are a variety of methods for preparing alumoxane and modified alumoxanes, non-limiting examples of which are described in U.S. Patent No. 4,665,208, 4,952,540, 5,091,352, 5,206,199, 5,204,419, 4,874,734, 4,924,018, 4,908,463, 4,968,827, 5,308,815, 5,329,032, 5,248,801, 5,235,081, 5,157,137, 5,103,031, 5,391,793, 5,391,529, 5,693,838, 5,731,253, 5,731,451, 5,744,656, 5,847,177, 5,854,166, 5,856,256 and 5,939,346 and European publications EP-A-0 561 476, EP-B1-0 279 586, EP-A-0 594-218 and EP-B1-0 586 665, and PCT publications WO 94/10180 and WO 99/15534.

**[0023]** In one embodiment, the activators of the invention are represented by Formula (IIIa) or (IIIb)



or



or



**[0024]** In Formulae (IIIa), (IIIb) and (IIIc), M is a Group 13 atom, preferably boron or aluminum, and more preferably aluminum. (JY) represents a heterocyclic group attached to M. In (JY) the Y represents the heterocyclic group as a whole and J represents at least one heteroatom contained in group Y. M may be bonded to any atom contained in Y, but is preferably bonded to heteroatom J.



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**[0025]** Preferably, J is an atom selected from Group 15 or 16 of the Period Table of the Elements, more preferably J is nitrogen, oxygen, or sulfur and most preferably J is nitrogen.

**[0026]** Non-limiting examples of (JY) include pyrrolyl, imidazolyl, pyrazolyl, pyrrolidinyl, purinyl, carbazolyl, and indolyl groups.

5 **[0027]** Heterocyclic group (JY) may be unsubstituted or substituted with one or a combination of substituent groups. Examples of suitably substituents include hydrogen, halogen, linear or branched alkyl, alkenyl or alkynyl radicals, cycloalkyl radicals, aryl radicals, aryl substituted alkyl radicals, acyl radicals, aroyl radicals, alkoxy radicals, aryloxy radicals, alkylthio radicals, dialkylamino radicals, alkoxycarbonyl radicals, aryloxy carbonyl radicals, carbomoyl radicals, alkyl- or dialkyl- carbamoyl radicals, acyloxy radicals, acylamino radicals, aroylamino radicals, straight, branched or cyclic, alkylene radicals, or combination thereof. The substituent groups may also be substituted with halogens, particularly fluorine, or heteroatoms or the like.

15 **[0028]** Non-limiting examples of substituents include methyl, ethyl, propyl, butyl, pentyl, hexyl, cyclopentyl, cyclohexyl, benzyl or phenyl groups and the like, including all their isomers, for example tertiary butyl, isopropyl, and the like. Other examples of substituents include fluoromethyl, fluoroethyl, difluoroethyl, iodopropyl, bromohexyl, chlorobenzyl.

**[0029]** Preferably one or more positions on the heterocyclic group (JY) is substituted with a halogen atom or a halogen atom containing group, preferably the halogen is chlorine, bromine or fluorine, more preferably bromine or fluorine, and most preferably fluorine. Even more preferably, the substituent is a fluorine atom or a fluorinated aryl group such as a fluorinated phenyl group.

25 **[0030]** In Formula (IIIa) n is 1 or 2. In Formula (IIIb) n is 2. In Formula (IIIc) n is a number from 1 to 1000 preferably 1 to 100, more preferably 5 to 50, and even more preferably 5-25;

**[0031]** m is a number from 1 to 10;

**[0032]**  $x + y =$  the valence of M in Formula (IIIa).  $x + y =$  the valence of M - 1 in Formulae (IIIb); and  $x + y =$  valence of M - 2 in Formula (IIIc).

30 **[0033]** Each R' is independently a substituent group bonded to M. Non-limiting examples of substituent R' groups include hydrogen, linear or branched alkyl or alkenyl radicals, alkynyl radicals, cycloalkyl radicals, aryl radicals, acyl radicals, aroyl radicals, alkoxy radicals, aryloxy radicals, alkylthio radicals, dialkylamino radicals, alkoxycarbonyl radicals, aryloxy carbonyl radicals, carbomoyl radicals, alkyl- or dialkyl- carbamoyl radicals, acyloxy

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radicals, acylamino radicals, aroylamino radicals, straight, branched or cyclic alkylene radicals, or combination thereof.

**[0034]** Each R' may be a methyl, ethyl, propyl, butyl, pentyl, hexyl, cyclopentyl, cyclohexyl, benzyl or phenyl group, including all their isomers, for example tertiary butyl, isopropyl, and the like. Other suitable substituents R' include hydrocarbyl radicals such as fluoromethyl, fluoroethyl, difluoroethyl, iodopropyl, bromohexyl, chlorobenzyl; hydrocarbyl substituted organometalloid radicals including trimethylsilyl, trimethylgermyl, methyldiethylsilyl and the like; halocarbyl-substituted organometalloid radicals including tris(trifluoromethyl)-silyl, methyl-bis(difluoromethyl)silyl, bromomethyldimethylgermyl and the like; disubstituted boron radicals including dimethylboron for example; disubstituted pnictogen radicals including dimethylamine, dimethylphosphine, diphenylamine, methylphenylphosphine; and chalcogen radicals including methoxy, ethoxy, propoxy, phenoxy, methylsulfide and ethylsulfide.

**[0035]** Other substituents R' include the atoms carbon, silicon, boron, aluminum, nitrogen, phosphorous, oxygen, tin, sulfur, or germanium and the like. Substituent R' groups also include olefins such as but not limited to olefinically unsaturated substituents including vinyl-terminated ligands, for example but-3-enyl, prop-2-enyl, hex-5-enyl and the like. Also, at least two R groups, preferably two adjacent R' groups, may be joined to form a ring structure having from 3 to 30 atoms selected from carbon, nitrogen, oxygen, phosphorous, silicon, germanium, aluminum, boron or a combination thereof. Also, a substituent group R' such as 1-butanyl may form a carbon sigma bond to the metal M.

**[0036]** In one embodiment, each R' a substituted or unsubstituted alkyl group and/or a substituted or unsubstituted aryl group, and preferably each R' is an alkyl group containing 1 to 30 carbon atoms.

**[0037]** In one embodiment, In Formulae (IIIa), (IIIb) or (IIIc) M is Al or B, preferably Al, J is a nitrogen atom contained in heterocyclic group Y and preferably (JY) is an substituted or unsubstituted indolyl group where the substituents are preferably hydrogen, halogen, an alkyl group, a halogenated or partially halogenated alkyl group, and aryl group, a halogenated or partially halogenated aryl group, an aryl substituted alkyl group, a halogenated or partially halogenated aryl substituted alkyl group, or combinations thereof, preferably J is bound to M, and R' a substituted or unsubstituted alkyl group and/or a substituted or unsubstituted aryl group, preferably an alkyl group containing 1 to 30 carbon atoms.

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[0038] In another embodiment, in Formulae (IIIa), (IIIb) or (IIIc) M is Al or B, preferably Al, J is a nitrogen atom bonded to M and contained in a heterocyclic group Y where the heterocyclic ligand (JY) is an unsubstituted heterocyclic group. In another embodiment, one or more positions on the heterocyclic group is substituted with a chlorine, bromine and/or  
 5 fluorine atoms or with chlorine bromine and/or fluorine atom containing groups, more preferably with fluorine atoms or fluorine atom containing groups and R' a substituted or unsubstituted alkyl group and/or a substituted or unsubstituted aryl group, preferably an alkyl group containing 1 to 30 carbon atoms. In another embodiment, (JY) is not a perhalogenated group.

10 [0039] In another embodiment, in Formulae (IIIa), (IIIb) or (IIIc) M is Al or B, preferably Al, J is a nitrogen atom bonded to M and contained in a heterocyclic group Y where the heterocyclic ligand (JY) is an unsubstituted heterocyclic group. In another embodiment, one or more positions on the heterocyclic group is substituted with a halogen such as chlorine bromine and/or fluorine atoms or with a halogen atom, such as a chlorine, bromine and/or  
 15 fluorine containing groups. More preferably the heterocyclic group is substituted with fluorine atoms or fluorine atom containing groups. In another embodiment, at least one R' is bonded to a support material, preferably a silica support material.

[0040] In another embodiment, one or more of the activators of the invention may be used in combination with each other or in combination with other activators or methods of  
 20 activation. For example, the activators of the invention may be used in combination with other activators including aluminoxane, modified aluminoxane, tri (n-butyl) ammonium tetrakis (pentafluorophenyl) boron, a trisperfluorophenyl boron metalloid precursor or a trisperfluoronaphthyl boron metalloid precursor, polyhalogenated heteroborane anions, trimethylaluminum, triethylaluminum, triisobutylaluminum, tri-n-hexylaluminum, tri-n-  
 25 octylaluminum, tris (2, 2', 2''- nona-fluorobiphenyl) fluoroaluminate, perchlorates, periodates, iodates and hydrates, (2,2'-bisphenyl-ditrimethylsilicate)•4THF and organo-boron-aluminum compound, silylium salts and dioctadecylmethylammonium-bis(tris(pentafluorophenyl)borane)-benzimidazole or combinations thereof.

### 30 Catalyst Compositions

[0041] The activator of the invention may be utilized in conjunction with any suitable polymerization catalyst compound or compounds to polymerize olefin(s). Examples of suitable catalyst compounds include bulky ligand metallocene catalyst compositions, Group 15 atom

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containing metal polymerization catalyst compositions, and phenoxide transition metal catalyst compositions. The following is a non-limiting discussion of the various polymerization catalysts which may be utilized with the activators of the invention.

5 **Bulky Ligand Metallocene Catalyst Compositions**

[0042] The activator complexes of the present invention may be used to activate bulky ligand metallocene catalyst compositions. Generally, these catalyst compounds include half and full sandwich compounds having one or more bulky ligands bonded to at least one metal atom. Typical bulky ligand metallocene compounds are described as containing one or more

10 bulky ligand(s) and one or more leaving group(s) bonded to at least one metal atom.

[0043] The bulky ligands may be open, acyclic, fused ring(s) or ring system(s), or a combination thereof. The ring(s) or ring system(s) of these bulky ligands are typically composed of atoms selected from Groups 13 to 16 atoms of the Periodic Table of the Elements. Preferably the atoms are selected from the group consisting of carbon, nitrogen, oxygen, silicon, sulfur, phosphorous, germanium, boron and aluminum or a combination thereof. Most preferably the ring(s) or ring system(s) are composed of carbon atoms such as but not limited to those cyclopentadienyl ligands or cyclopentadienyl-type ligand structures. The bulky ligands may also be other similar functioning ligand structure such as a pentadiene, a cyclooctatetradienyl or an imide ligand. The metal atom is preferably selected from Groups 3 through 15 and the lanthanide or actinide series of the Periodic Table of the Elements. Preferably the metal is a transition metal from Groups 4 through 12, more preferably Groups 4, 5 and 6, and most preferably the transition metal is from Group 4, especially Ti or Zr or Hf.

[0044] In one embodiment, the bulky ligand metallocene catalyst compounds, which may be utilized with the activator complex of the invention, may be represented by Formula (IV):



Formula (IV)

where M is a metal atom from the Periodic Table of the Elements and may be a Group 3 to 12 metal or from the lanthanide or actinide series of the Periodic Table of the Elements, preferably M is a Group 4, 5 or 6 transition metal, more preferably M is zirconium, hafnium or titanium. The bulky ligands,  $L^A$  and  $L^B$ , are open, acyclic or fused ring(s) or ring system(s) and are any ancillary ligand system, including unsubstituted or substituted, cyclopentadienyl ligands or

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cyclopentadienyl-type ligands, heteroatom substituted and/or heteroatom containing cyclopentadienyl-type ligands. Non-limiting examples of bulky ligands include cyclopentadienyl ligands, cyclopentaphenanthrenyl ligands, indenyl ligands, benzindenyl ligands, fluorenyl ligands, octahydrofluorenyl ligands, cyclooctatetraendiyl ligands, 5 cyclopentacyclododecene ligands, azenyl ligands, azulene ligands, pentalene ligands, phosphoyl ligands, phosphinimine (WO 99/40125), pyrrolyl ligands, pyrozoilyl ligands, carbazolyl ligands, borabenzene ligands and the like, including hydrogenated versions thereof, for example tetrahydroindenyl ligands. In another embodiment,  $L^A$  and  $L^B$  may comprise one or more heteroatoms, for example, nitrogen, silicon, boron, germanium, sulfur and 10 phosphorous, in combination with carbon atoms to form an open, acyclic, or preferably a fused, ring or ring system, for example, a hetero-cyclopentadienyl ancillary ligand. Other  $L^A$  and  $L^B$  bulky ligands include but are not limited to bulky amides, phosphides, alkoxides, aryloxides, imides, carbolides, borollides, porphyrins, phthalocyanines, corrins and other polyazomacrocycles. Independently, each  $L^A$  and  $L^B$  may be the same or different type of 15 bulky ligand that is bonded to M. In one embodiment of Formula (IV) only one of either  $L^A$  or  $L^B$  is present.

**[0045]** Independently, each  $L^A$  and  $L^B$  may be unsubstituted or substituted with a combination of substituent groups R. Non-limiting examples of substituent groups R include one or more from the group selected from hydrogen, or linear, branched alkyl radicals, or 20 alkenyl radicals, alkynyl radicals, cycloalkyl radicals or aryl radicals, acyl radicals, aroyl radicals, alkoxy radicals, aryloxy radicals, alkylthio radicals, dialkylamino radicals, alkoxycarbonyl radicals, aryloxy carbonyl radicals, carbomoyl radicals, alkyl- or dialkyl-carbamoyl radicals, acyloxy radicals, acylamino radicals, aroylamino radicals, straight, branched or cyclic, alkylene radicals, or combination thereof. In a preferred embodiment, 25 substituent groups R have up to 50 non-hydrogen atoms, preferably from 1 to 30 carbon, that can also be substituted with halogens or heteroatoms or the like. Non-limiting examples of alkyl substituents R include methyl, ethyl, propyl, butyl, pentyl, hexyl, cyclopentyl, cyclohexyl, benzyl or phenyl groups and the like, including all their isomers, for example tertiary butyl, isopropyl, and the like. Other hydrocarbyl radicals include fluoromethyl, fluoroethyl, 30 difluoroethyl, iodopropyl, bromohexyl, chlorobenzyl and hydrocarbyl substituted organometalloid radicals including trimethylsilyl, trimethylgermyl, methyldiethylsilyl and the like; and halocarbyl-substituted organometalloid radicals including tris(trifluoromethyl)-silyl, methyl-bis(difluoromethyl)silyl, bromomethyldimethylgermyl and the like; and disubstituted

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boron radicals including dimethylboron for example; and disubstituted pnictogen radicals including dimethylamine, dimethylphosphine, diphenylamine, methylphenylphosphine, chalcogen radicals including methoxy, ethoxy, propoxy, phenoxy, methylsulfide and ethylsulfide. Non-hydrogen substituents R include the atoms carbon, silicon, boron, aluminum, nitrogen, phosphorous, oxygen, tin, sulfur, germanium and the like, including olefins such as but not limited to olefinically unsaturated substituents including vinyl-terminated ligands, for example but-3-enyl, prop-2-enyl, hex-5-enyl and the like. Also, at least two R groups, preferably two adjacent R groups, are joined to form a ring structure having from 3 to 30 atoms selected from carbon, nitrogen, oxygen, phosphorous, silicon, germanium, aluminum, boron or a combination thereof. Also, a substituent group R group such as 1-butanyl may form a carbon sigma bond to the metal M.

**[0046]** Other ligands may be bonded to the metal M, such as at least one leaving group Q. For the purposes of this patent specification and appended claims the term "leaving group" is any ligand that can be abstracted from a bulky ligand metallocene catalyst compound to form a bulky ligand metallocene catalyst cation capable of polymerizing one or more olefin(s). In one embodiment, Q is a monoanionic labile ligand having a sigma-bond to M. Depending on the oxidation state of the metal, the value for n is 0, 1 or 2 or such that Formula (IV) above represents a neutral bulky ligand metallocene catalyst compound.

**[0047]** Non-limiting examples of Q ligands include weak bases such as amines, phosphines, ethers, carboxylates, dienes, hydrocarbyl radicals having from 1 to 20 carbon atoms, hydrides or halogens and the like or a combination thereof. In another embodiment, two or more Q's form a part of a fused ring or ring system. Other examples of Q ligands include those substituents for R as described above and including cyclobutyl, cyclohexyl, heptyl, tolyl, trifluoromethyl, tetramethylene, pentamethylene, methyldiene, methoxy, ethoxy, propoxy, phenoxy, bis(N-methylanilide), dimethylamide, dimethylphosphide radicals and the like.

**[0048]** In another embodiment, the activator complex of the invention is utilized with the bulky ligand metallocene catalyst compounds of Formula (V) where  $L^A$  and  $L^B$  are bridged to each other by at least one bridging group, A, as represented in the following formula:



These bridged compounds represented by Formula (V) are known as bridged, bulky ligand metallocene catalyst compounds.  $L^A$ ,  $L^B$ , M, Q and n are as defined above. Non-limiting examples of bridging group A include bridging groups containing at least one Group 13 to 16

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atom, often referred to as a divalent moiety such as but not limited to at least one of a carbon, oxygen, nitrogen, silicon, aluminum, boron, germanium and tin atom or a combination thereof. Preferably bridging group A contains a carbon, silicon or germanium atom, most preferably A contains at least one silicon atom or at least one carbon atom. The bridging group A may also  
 5 contain substituent groups R as defined above including halogens and iron. Non-limiting examples of bridging group A may be represented by  $R'_2C$ ,  $R'_2Si$ ,  $R'_2Si R'_2Si$ ,  $R'_2Ge$ ,  $R'_2P$ , where  $R'$  is independently, a radical group which is hydride, hydrocarbyl, substituted hydrocarbyl, halocarbyl, substituted halocarbyl, hydrocarbyl-substituted organometalloid, halocarbyl-substituted organometalloid, disubstituted boron, disubstituted pnictogen,  
 10 substituted chalcogen, or halogen or two or more  $R'$  may be joined to form a ring or ring system. In one embodiment, the bridged, bulky ligand metallocene catalyst compounds of Formula (V) have two or more bridging groups A (EP 664 301 B1).

**[0049]** In another embodiment, the activator complex of the invention may be utilized with bulky ligand metallocene catalyst compounds where the R substituents on the bulky  
 15 ligands  $L^A$  and  $L^B$  of Formulas (IV) and (V) are substituted with the same or different number of substituents on each of the bulky ligands. In another embodiment, the bulky ligands  $L^A$  and  $L^B$  of formulas (IV) and (V) are different from each other.

**[0050]** In another embodiment, the activator complex of the invention may be utilized with other bulky ligand metallocene catalyst compounds such as those described in U.S. Patent  
 20 Nos. 5,064,802, 5,145,819, 5,149,819, 5,243,001, 5,239,022, 5,276,208, 5,296,434, 5,321,106, 5,329,031, 5,304,614, 5,677,401, 5,723,398, 5,753,578, 5,854,363, 5,856,547, 5,858,903, 5,859,158, 5,900,517 and 5,939,503 and PCT publications WO 93/08221, WO 93/08199, WO 95/07140, WO 98/11144, WO 98/41530, WO 98/41529, WO 98/46650, WO 99/02540 and WO 99/14221 and European publications EP-A-0 578 838, EP-A-0 638 595, EP-B-0 513 380,  
 25 EP-A1-0 816 372, EP-A2-0 839 834, EP-B1-0 632 819, EP-B1-0 748 821 and EP-B1-0 757 996.

**[0051]** In another embodiment, the activator complex of the invention may be utilized with bulky ligand metallocene catalysts which include bridged heteroatom, mono-bulky ligand metallocene compounds. These types of catalysts and catalyst systems are described in, for  
 30 example, PCT publication WO 92/00333, WO 94/07928, WO 91/ 04257, WO 94/03506, WO96/00244, WO 97/15602 and WO 99/20637 and U.S. Patent Nos. 5,057,475, 5,096,867, 5,055,438, 5,198,401, 5,227,440 and 5,264,405 and European publication EP-A-0 420 436.

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**[0052]** In this embodiment, the activator complexes of the invention are utilized with a bulky ligand metallocene catalyst compound represented by Formula (VI):



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where M is a Group 3 to 12 metal atom or a metal selected from the Group of actinides and lanthanides of the Periodic Table of the Elements, preferably M is a Group 4 to 12 transition metal, and more preferably M is a Group 4, 5 or 6 transition metal, and most preferably M is a Group 4 transition metal in any oxidation state, especially Ti or Zr or Hf,  $L^C$  is a substituted or unsubstituted bulky ligand bonded to M; J is bonded to M; A is bonded to  $L^C$  and J; J is a heteroatom ancillary ligand; and A is a bridging group; Q is a univalent anionic ligand; and n is the integer 0, 1 or 2. In Formula (VI) above,  $L^C$ , A and J form a fused ring system. In an embodiment,  $L^C$  of formula (VI) is as defined above for  $L^A$ , A, M and Q of formula (VI) are as defined above in formula (V).

10 **[0053]** In Formula (VI) J is a heteroatom containing ligand in which J is an element with a coordination number of three from Group 15 or an element with a coordination number of two from Group 16 of the Periodic Table of the Elements. Preferably J contains a nitrogen, phosphorus, oxygen or sulfur atom with nitrogen being most preferred.

**[0054]** In another embodiment, the activator complex of the invention is utilized with a bulky ligand metallocene catalyst compound which is a complex of a metal, preferably a transition metal, a bulky ligand, preferably a substituted or unsubstituted pi-bonded ligand, and one or more heteroallyl moieties, such as those described in U.S. Patent Nos. 5,527,752 and 5,747,406 and EP-B1-0 735 057.

25 **[0055]** In another embodiment the activator complex of the invention is utilized with a ligand metallocene catalyst compound which may be represented by Formula (VII):



where M is a Group 3 to 16 metal, preferably a Group 4 to 12 transition metal, and most preferably a Group 4, 5 or 6 transition metal;  $L^D$  is a bulky ligand that is bonded to M; each Q is independently bonded to M and  $Q_2(YZ)$  forms a uncharged polydentate ligand; A or Q is a univalent anionic ligand also bonded to M; X is a univalent anionic group when n is 2 or X is a divalent anionic group when n is 1; n is 1 or 2.

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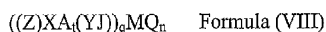
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**[0056]** In Formula (VII), L and M are as defined above for Formula (IV). Q is as defined above for Formula (IV), preferably Q is selected from the group consisting of -O-, -NR-, -CR<sub>2</sub>- and -S-; Y is either C or S; Z is selected from the group consisting of -OR, -NR<sub>2</sub>, -CR<sub>3</sub>, -SR, -SiR<sub>3</sub>, -PR<sub>2</sub>, -IL, and substituted or unsubstituted aryl groups, with the proviso that when Q is -NR- then Z is selected from one of the group consisting of -OR, -NR<sub>2</sub>, -SR, -SiR<sub>3</sub>, -PR<sub>2</sub> and -H; R is selected from a group containing carbon, silicon, nitrogen, oxygen, and/or phosphorus, preferably where R is a hydrocarbon group containing from 1 to 20 carbon atoms, most preferably an alkyl, cycloalkyl, or an aryl group; n is an integer from 1 to 4, preferably 1 or 2; X is a univalent anionic group when n is 2 or X is a divalent anionic group when n is 1; preferably X is a carbamate, carboxylate, or other heteroallyl moiety described by the Q, Y and Z combination.

**[0057]** In another embodiment, the activator complex of the invention is utilized with a bulky ligand metallocene catalyst compounds, which include heterocyclic ligand complexes where the bulky ligands, the ring(s) or ring system(s), include one or more heteroatoms or a combination thereof. Non-limiting examples of heteroatoms include a Group 13 to 16 element, preferably nitrogen, boron, sulfur, oxygen, aluminum, silicon, phosphorous and tin. Examples of these bulky ligand metallocene catalyst compounds are described in WO 96/33202, WO 96/34021, WO 97/17379 and WO 98/22486 and EP-A1-0 874 005 and U.S. Patent No. 5,637,660, 5,539,124, 5,554,775, 5,756,611, 5,233,049, 5,744,417, and 5,856,258.

**[0058]** In another embodiment, the activator complex of the invention may be utilized with bulky ligand metallocene catalyst compounds, which include complexes known as transition metal catalysts based on bidentate ligands containing pyridine or quinoline moieties, such as those described in U.S. Application Serial No. 09/103,620 filed June 23, 1998. In another embodiment, the bulky ligand metallocene catalyst compounds are those described in PCT publications WO 99/01481 and WO 98/42664.

**[0059]** In another embodiment, the activator complex of the invention may be utilized with a bulky ligand metallocene catalyst compounds which may be represented by Formula (VIII):



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where M is a metal selected from Group 3 to 13 or lanthanide and actinide series of the Periodic Table of the Elements; Q is bonded to M and each Q is a monovalent, bivalent, or trivalent anion; X and Y are bonded to M; one or more of X and Y are heteroatoms, preferably both X and Y are heteroatoms; Y is contained in a heterocyclic ring J, where J comprises from 2 to 50 non-hydrogen atoms, preferably 2 to 30 carbon atoms; Z is bonded to X, where Z comprises 1 to 50 non-hydrogen atoms, preferably 1 to 50 carbon atoms, preferably Z is a cyclic group containing 3 to 50 atoms, preferably 3 to 30 carbon atoms; t is 0 or 1; when t is 1, A is a bridging group joined to at least one of X, Y or J, preferably X and J; q is 1 or 2; n is an integer from 1 to 4 depending on the oxidation state of M. In one embodiment, where X is oxygen or sulfur then Z is optional. In another embodiment, where X is nitrogen or phosphorous then Z is present. In an embodiment, Z is preferably an aryl group, more preferably a substituted aryl group.

**[0060]** It is also within the scope of this invention, in one embodiment, that the bulky ligand metallocene catalyst compounds, which may be utilized with the activator complex of the invention include complexes of  $\text{Ni}^{2+}$  and  $\text{Pd}^{2+}$  described in the articles Johnson, et al., "New Pd(II)- and Ni(II)- Based Catalysts for Polymerization of Ethylene and  $\alpha$ -Olefins", J. Am. Chem. Soc. 1995, 117, 6414-6415 and Johnson, et al., "Copolymerization of Ethylene and Propylene with Functionalized Vinyl Monomers by Palladium(II) Catalysts", J. Am. Chem. Soc., 1996, 118, 267-268, and WO 96/23010 published August 1, 1996, WO 99/02472, U.S. Patent Nos. 5,852,145, 5,866,663 and 5,880,241. These complexes can be either dialkyl ether adducts, or alkylated reaction products of the described dihalide complexes that can be activated to a cationic state by the activators of this invention described below.

**[0061]** Also included as bulky ligand metallocene catalyst are those diimine based ligands of Group 8 to 10 metal compounds disclosed in PCT publications WO 96/23010 and WO 97/48735 and Gibson, et al., Chem. Comm., pp. 849-850 (1998).

**[0062]** Other bulky ligand metallocene catalysts, which may be utilized with the activator complex of the invention, are those Group 5 and 6 metal imido complexes described in EP-A2-0 816 384 and U.S. Patent No. 5,851,945. In addition, bridged bis(amido) catalyst compounds are described in WO 96/27439. Other bulky ligand metallocene catalysts are described as bis(hydroxy aromatic nitrogen ligands) in U.S. Patent No. 5,852,146. Other metallocene catalysts containing one or more Group 15 atoms include those described in WO 98/46651. Still another metallocene bulky ligand

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metallocene catalysts include those multinuclear bulky ligand metallocene catalysts as described in WO 99/20665.

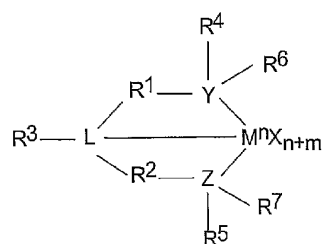
[0063] It is also contemplated that in one embodiment, the bulky ligand metallocene catalysts of the invention described above include their structural or optical or enantiomeric isomers (meso and racemic isomers, for example see U.S. Patent No. 5,852,143.

#### **Group 15 Atom Containing Polymerization Catalysts**

[0064] The activator complexes of the invention may also be utilized with Group 15 atom containing polymerization catalyst compounds. Generally, these catalysts includes a Group 3 to 14 metal atom, preferably a Group 3 to 7, more preferably a Group 4 to 6, and even more preferably a Group 4 metal atom, bound to at least one leaving group and also bound to at least two Group 15 atoms, at least one of which is also bound to a Group 15 or 16 atom through another group.

[0065] Preferably, at least one of the Group 15 atoms is also bound to a Group 15 or 16 atom through another group which may be a C<sub>1</sub> to C<sub>20</sub> hydrocarbon group, a heteroatom containing group, silicon, germanium, tin, lead, or phosphorus, wherein the Group 15 or 16 atom may also be bound to nothing or a hydrogen, a Group 14 atom containing group, a halogen, or a heteroatom containing group, and wherein each of the two Group 15 atoms are also bound to a cyclic group and may optionally be bound to hydrogen, a halogen, a heteroatom or a hydrocarbyl group, or a heteroatom containing group.

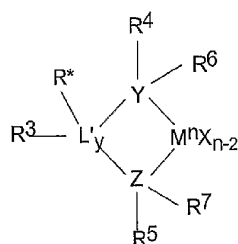
[0066] Group 15 atom containing metal polymerization catalyst compounds may be represented by Formulae (IX) or (X):



Formula (IX) or

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Formula (X)

- 5 wherein M is a transition metal, preferably a Group 3 to 14 main group metal, preferably a Group 4, 5, or 6 metal, and more preferably a Group 4 metal, and most preferably zirconium, titanium or hafnium;
- each X is independently a leaving group, preferably an anionic leaving group, and more preferably hydrogen, a hydrocarbyl group, a heteroatom, or a halogen, and most preferably an alkyl or an aryl substituted alkyl;
- 10 y is 0 or 1 (when y is 0 group L' is absent);
- n is the oxidation state of M, preferably +3, +4, or +5, and more preferably +4;
- m is the formal charge of the YZL' or the YZL' ligand, preferably 0, -1, -2 or -3, and more preferably -2;
- 15 L is a Group 15 or 16 element, preferably nitrogen;
- L' is a Group 15 or 16 element or Group 14 containing group, preferably carbon, silicon or germanium;
- Y is a Group 15 element, preferably nitrogen or phosphorus, and more preferably nitrogen;
- Z is a Group 15 element, preferably nitrogen or phosphorus, and more preferably nitrogen;
- 20 R<sup>1</sup> and R<sup>2</sup> are independently a C<sub>1</sub> to C<sub>20</sub> hydrocarbon group, a heteroatom containing group having up to twenty carbon atoms, silicon, germanium, tin, lead, or phosphorus, preferably a C<sub>2</sub> to C<sub>20</sub> alkyl, aryl or aralkyl group, more preferably a linear, branched or cyclic C<sub>2</sub> to C<sub>20</sub> alkyl group, most preferably a C<sub>2</sub> to C<sub>6</sub> hydrocarbon group;
- R<sup>3</sup> is absent, a hydrocarbon group, hydrogen, a halogen, a heteroatom containing group,
- 25 preferably a linear, cyclic or branched alkyl group having 1 to 20 carbon atoms, more preferably R<sup>3</sup> is absent, hydrogen or an alkyl group, and most preferably hydrogen;

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$R^4$  and  $R^5$  are independently an alkyl group, an aryl group, substituted aryl group, a cyclic alkyl group, a substituted cyclic alkyl group, a cyclic arylalkyl group, a substituted cyclic arylalkyl group or a multiple ring system, preferably having up to 20 carbon atoms, more preferably between 3 and 10 carbon atoms, and even more preferably a  $C_1$  to  $C_{20}$  hydrocarbon group, a  $C_1$  to  $C_{20}$  aryl group or a  $C_1$  to  $C_{20}$  arylalkyl group, or a

heteroatom containing group, for example  $PR_3$ , where R is an alkyl group;  
 $R^1$  and  $R^2$  may be interconnected to each other, and/or  $R^4$  and  $R^5$  may be interconnected to each other;

$R^6$  and  $R^7$  are independently absent, or hydrogen, an alkyl group, halogen, heteroatom or a hydrocarbyl group, preferably a linear, cyclic or branched alkyl group having 1 to 20 carbon atoms, more preferably absent; and

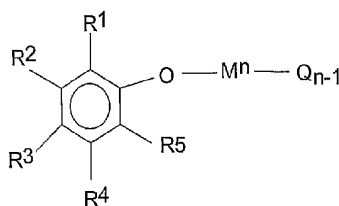
$R^*$  is absent, or is hydrogen, a Group 14 atom containing group, a halogen, a heteroatom containing group.

**[0067]** By "formal charge of the YZL or YZL' ligand", it is meant the charge of the entire ligand absent the metal and the leaving groups X. By " $R^1$  and  $R^2$  may also be interconnected" it is meant that  $R^1$  and  $R^2$  may be directly bound to each other or may be bound to each other through other groups. By " $R^4$  and  $R^5$  may also be interconnected" it is meant that  $R^4$  and  $R^5$  may be directly bound to each other or may be bound to each other through other groups.

#### **Phenoxide transition metal catalyst compositions**

**[0068]** The activator complexes of the invention may also be used with phenoxide transition metal catalyst compounds. Generally, these complexes are heteroatom substituted phenoxide ligated Group 3 to 10 transition metal or lanthanide metal compounds wherein the metal is bound to the oxygen of the phenoxide group.

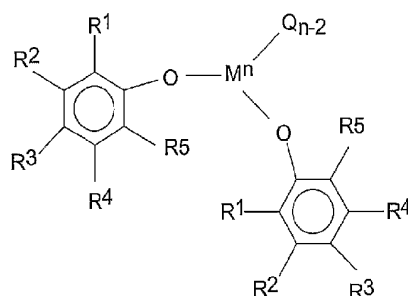
**[0069]** Phenoxide transition metal catalyst compounds may be represented by Formulae XI or XII:



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Formula (XI)

or



Formula (XII)

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wherein  $R^1$  is hydrogen or a  $C_4$  to  $C_{100}$  group, preferably a tertiary alkyl group, preferably a  $C_4$  to  $C_{20}$  alkyl group, preferably a  $C_4$  to  $C_{20}$  tertiary alkyl group, preferably a neutral  $C_4$  to  $C_{100}$  group and may or may not also be bound to M;

at least one of  $R^2$  to  $R^5$  is a heteroatom containing group, the rest of  $R^2$  to  $R^5$  are independently  
 10 hydrogen or a  $C_1$  to  $C_{100}$  group, preferably a  $C_4$  to  $C_{20}$  alkyl group, preferred examples of which include butyl, isobutyl, t-butyl, pentyl, hexyl, heptyl, isohexyl, octyl, isooctyl, decyl, nonyl, dodecyl, and any of  $R^2$  to  $R^5$  also may or may not be bound to M;

Each  $R^1$  to  $R^5$  group may be independently substituted or unsubstituted with other atoms, including heteroatoms or heteroatom containing group(s);

15 O is oxygen;

M is a Group 3 to Group 10 transition metal or lanthanide metal, preferably a Group 4 metal, preferably M is Ti, Zr or Hf;

n is the valence state of the metal M, preferably 2, 3, 4, or 5; and

Q is, and each Q may be independently be, an alkyl, halogen, benzyl, amide, carboxylate, carbamate, thiolate, hydride or alkoxide group, or a bond to an R group containing a  
 20 heteroatom which may be any of  $R^1$  to  $R^5$ .

**[0070]** A heteroatom containing group may be any heteroatom or a heteroatom bound to carbon, silicon or another heteroatom. Preferred heteroatoms include boron, aluminum, silicon, nitrogen, phosphorus, arsenic, tin, lead, antimony, oxygen, selenium, and tellurium.  
 25 Particularly preferred heteroatoms include nitrogen, oxygen, phosphorus, and sulfur. Even more particularly preferred heteroatoms include nitrogen and oxygen. The heteroatom itself

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may be directly bound to the phenoxide ring or it may be bound to another atom or atoms that are bound to the phenoxide ring. The heteroatom containing group may contain one or more of the same or different heteroatoms. Preferred heteroatom containing groups include imines, amines, oxides, phosphines, ethers, ketones, oxazolines heterocyclics, oxazolines, thioethers, and the like. Particularly preferred heteroatom containing groups include imines. Any two adjacent R groups may form a ring structure, preferably a 5 or 6 membered ring. Likewise the R groups may form multi-ring structures. In one embodiment any two or more R groups do not form a 5 membered ring.

[0071] In a preferred embodiment the heteroatom substituted phenoxide transition metal compound is an iminophenoxide Group 4 transition metal compound, and more preferably an iminophenoxidezirconium compound.

#### **Other Bulky Ligand Metallocene Catalyst Compounds**

[0072] Other catalysts are those Group 5 and 6 metal imido complexes described in EP-A2-0 816 384 and U.S. Patent No. 5,851,945. In addition, other catalysts include bridged bis(arylamido) Group 4 compounds described by D.H. McConville, et al., in Organometallics 1195, 14, 5478-5480. Bridged bis(amido) catalyst compounds are described in WO 96/27439. Other suitable catalysts are described as bis(hydroxy aromatic nitrogen ligands) in U.S. Patent No. 5,852,146. Other catalysts containing one or more Group 15 atoms include those described in WO 98/46651. Still other catalysts include those multinuclear bulky ligand metallocene catalysts as described in WO 99/20665.

[0073] It is also contemplated that in one embodiment, the activator complexes of the inventions are utilized with bulky ligand metallocene catalysts including their structural or optical or enantiomeric isomers (meso and racemic isomers, for example see U.S. Patent No. 5,852,143.

[0074] In another embodiment, it is further contemplated that the polymerization catalysts, described above may be used in combination with the activator(s) of the present invention.

[0075] In one embodiment, the mole ratio of the metal of the activator component of the invention to the metal component is preferably in the range of ratios of between 0.3:1 to 3:1.

#### **Supported Catalyst Systems of the Invention**

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[0076] The activator of the invention and/or the polymerization catalyst compound may be combined with one or more support materials or carriers, using one of the support methods known in the art or as described below. For example, in one embodiment the activator is in a supported form, for example deposited on, contacted with, vaporized with, bonded to, or incorporated within, adsorbed or absorbed in, or on, a support or carrier. In another embodiment, the activator and a catalyst compound may be deposited on, contacted with, vaporized with, bonded to, or incorporated within, adsorbed or absorbed in, or on, a support or carrier.

[0077] The terms "support" or "carrier", for purposes of this patent specification, are used interchangeably and are any support material, preferably a porous support material, including inorganic or organic support materials. Non-limiting examples of inorganic support materials include inorganic oxides and inorganic chlorides. Other carriers include resinous support materials such as polystyrene, functionalized or crosslinked organic supports, such as polystyrene, divinyl benzene, polyolefins, or polymeric compounds, zeolites, talc, clays, or any other organic or inorganic support material and the like, or mixtures thereof.

[0078] In one embodiment, the heterocyclic compounds and the aluminum alkyl and/or the alumoxanes described above are combined with one or more support materials or carriers. In another embodiment the heterocyclic compound is combined with a support material, preferably silica, treated with the alkylaluminum or the alumoxane compound, such that the support has aluminum alkyl groups bonded thereto. The supported catalyst systems of the invention may be prepared, generally, by the reaction of the heterocyclic compound with an aluminum alkyl or aluminoxane, the addition of the catalyst precursor, followed by addition of a support material such as silica or alumina.

[0079] The support materials utilized may be any of the conventional support materials. Preferably the supported material is a porous support material, for example, talc, inorganic oxides and inorganic chlorides. Other support materials include resinous support materials such as polystyrene, functionalized or crosslinked organic supports, such as polystyrene divinyl benzene polyolefins or polymeric compounds, zeolites, clays, or any other organic or inorganic support material and the like, or mixtures thereof.

[0080] The preferred support materials are inorganic oxides that include those Group 2, 3, 4, 5, 13 or 14 metal oxides. The preferred supports include silica, fumed silica, alumina (WO 99/60033), silica-alumina and mixtures thereof. Other useful supports include magnesia, titania, zirconia, magnesium chloride (U.S. Patent No. 5,965,477), montmorillonite (European



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Patent EP-B1 0 511 665), phyllosilicate, zeolites, talc, clays (U.S. Patent No. 6,034,187) and the like. Also, combinations of these support materials may be used, for example, silica-chromium, silica-alumina, silica-titania and the like. Additional support materials may include those porous acrylic polymers described in EP 0 767 184 B1. Other support materials include  
5 nanocomposites as described in PCT WO 99/47598, aerogels as described in WO 99/48605, spherulites as described in U.S. Patent No. 5,972,510 and polymeric beads as described in WO 99/50311. Another support is fumed silica available under the trade name Cabosil™ TS-610, available from Cabot Corporation. Fumed silica is typically a silica with particles 7 to 30 nanometers in size that has been treated with dimethylsilyldichloride such that a majority of the  
10 surface hydroxyl groups are capped.

**[0081]** In another embodiment, any of the conventionally known inorganic oxides, such as silica, support materials that retain hydroxyl groups after dehydration treatment methods will be suitable in accordance with the invention. Because of availability, both of silica and silica containing metal oxide based supports, for example, silica-alumina, are preferred. Silica  
15 particles, gels and glass beads are most typical.

**[0082]** These metal oxide compositions may additionally contain oxides of other metals, such as those of Al, K, Mg, Na, Si, Ti and Zr and should preferably be treated by thermal and/or chemical means to remove water and free oxygen. Typically such treatment is in a vacuum in a heated oven, in a heated fluidized bed or with dehydrating agents such as  
20 organo silanes, siloxanes, alkyl aluminum compounds, etc. The level of treatment should be such that as much retained moisture and oxygen as is possible is removed, but that a chemically significant amount of hydroxyl functionality is retained. Thus calcining at up to 800 °C or more up to a point prior to decomposition of the support material, for several hours is permissible, and if higher loading of supported anionic activator is desired, lower calcining  
25 temperatures for lesser times will be suitable. Where the metal oxide is silica, loadings to achieve from less than 0.1 mmol to 3.0 mmol activator/g SiO<sub>2</sub> are typically suitable and can be achieved, for example, by varying the temperature of calcining from 200 to 800+ °C. See Zhuralev, *et al*, Langmuir 1987, Vol. 3, 316 where correlation between calcining temperature and times and hydroxyl contents of silicas of varying surface areas is described.

**[0083]** The tailoring of hydroxyl groups available as attachment sites in this invention can also be accomplished by the pre-treatment with a less than stoichiometric amount of a chemical dehydrating agent. If calcining temperatures below 400 °C are employed,  
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difunctional coupling agents (e.g.,  $(\text{CH}_3)_3\text{SiCl}_2$ ) may be employed to cap hydrogen bonded pairs of silanol groups which are present under the less severe calcining conditions. See for example, "Investigation of Quantitative SiOH Determination by the Silane Treatment of Disperse Silica", Gorski, *et al*, Journ. of Colloid and Interface Science, Vol. 126, No. 2, Dec.

5 1988, for discussion of the effect of silane coupling agents for silica polymeric fillers that will also be effective for modification of silanol groups on the catalyst supports of this invention. Similarly, use of the Lewis acid in excess of the stoichiometric amount needed for reaction with the transition metal compounds will serve to neutralize excess silanol groups without significant detrimental effect for catalyst preparation or subsequent polymerization.

10 **[0084]** In another embodiment, the support is a Polymeric support, including hydroxyl-functional-group-containing polymeric substrates, but functional groups may be any of the primary alkyl amines, secondary alkyl amines, and others, where the groups are structurally incorporated in a polymeric chain and capable of an acid-base reaction with the Lewis acid such that a ligand filling one coordination site of the aluminum is protonated and replaced by the  
15 polymer incorporated functionality. See, for example, the functional group containing polymers of U.S. Patent No. 5,288,677.

**[0085]** It is preferred that the support material, most preferably an inorganic oxide, has a surface area in the range of from about 10 to about 700  $\text{m}^2/\text{g}$ , pore volume in the range of from about 0.1 to about 4.0 cc/g and average particle size in the range of from about 5 to about  
20 500  $\mu\text{m}$ . More preferably, the surface area of the support material is in the range of from about 50 to about 500  $\text{m}^2/\text{g}$ , pore volume of from about 0.5 to about 3.5 cc/g and average particle size of from about 10 to about 200  $\mu\text{m}$ . The average pore size of the carrier is typically in the range of from 10 to 1000Å, preferably 50 to about 500Å, and most preferably 75 to about 350Å.

25 **[0086]** The support materials may be treated chemically, for example with a fluoride compound as described in WO 00/12565. Other supported activators are described in for example WO 00/13792 that refers to supported boron containing solid acid complex.

**[0087]** In one embodiment, the support material having an alkylaluminum and/or the alumoxane compound bonded thereto may be prepared by combining the aluminum containing  
30 compound with the support material in a suitable solvent. In one embodiment, the combining is carried out at any suitable pressure and temperature under an inert atmosphere. Preferably the combining is at atmospheric pressure, ambient temperature under nitrogen. More preferably the mixture is heated to less than about 200° C, more preferably less than 150°C.

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The reactants are contacted for a suitable about of time for example, for at least about 1 minute, preferably about 1 minute to about 10 hours, more preferably for about 1 minute to about 3 hours.

**[0088]** Examples of supporting bulky ligand metallocene-type catalyst systems, which may be used to support the activator and/or catalyst systems of the invention are described in U.S. Patent Nos. 4,701,432, 4,808,561, 4,912,075, 4,925,821, 4,937,217, 5,008,228, 5,238,892, 5,240,894, 5,332,706, 5,346,925, 5,422,325, 5,466,649, 5,466,766, 5,468,702, 5,529,965, 5,554,704, 5,629,253, 5,639,835, 5,625,015, 5,643,847, 5,665,665, 5,698,487, 5,714,424, 5,723,400, 5,723,402, 5,731,261, 5,759,940, 5,767,032, 5,770,664, 5,846,895 and 5,939,348 and U.S. Application Serial Nos. 271,598 filed July 7, 1994 and 788,736 filed January 23, 1997 and PCT publications WO 95/32995, WO 95/14044, WO 96/06187 and WO 97/02297, and EP-B1-0 685 494.

**[0089]** In another embodiment, an antistatic agent or surface modifier, that is used in the preparation of the supported catalyst system as described in PCT publication WO 96/11960, may be used with catalyst systems including the activator compounds of the invention. The catalyst systems of the invention may also be prepared in the presence of an olefin, for example hexene-1.

**[0090]** In another embodiment, activator and/or catalyst system of the invention may be combined with a carboxylic acid salt of a metal ester, for example aluminum carboxylates such as aluminum mono, di- and tri- stearates, aluminum octoates, oleates and cyclohexylbutyrates, as described in U.S. Patents 6,300,436 and 6,306,984.

**[0091]** In another embodiment there is a method for producing a supported bulky ligand metallocene catalyst system, which maybe used to support the activator of the invention which is described below, and is described in U.S. Application Serial Nos. 265,533, filed June 24, 1994 and 265,532, filed June 24, 1994 and PCT publications WO 96/00245 and WO 96/00243 both published January 4, 1996. In this method, the catalyst compound is slurried in a liquid to form a catalyst solution or emulsion. A separate solution is formed containing the activator. The liquid may be any compatible solvent or other liquid capable of forming a solution or the like with the catalyst compounds and/or activator. In the most preferred embodiment the liquid is a cyclic aliphatic or aromatic hydrocarbon, most preferably toluene. The catalyst compound and activator solutions are mixed together heated and added to a heated porous support or a heated porous support is added to the solutions such that the total volume of the bulky ligand metallocene-type catalyst compound solution and the activator solution or the bulky ligand

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metallocene-type catalyst compound and activator solution is less than four times the pore volume of the porous support, more preferably less than three times, even more preferably less than two times; preferred ranges being from 1.1 times to 3.5 times range and most preferably in the 1.2 to 3 times range.

- 5 [0092] In one embodiment, a method of forming a supported catalyst system, the amount of liquid, in which the activator of the invention and/or a catalyst compound is present, is in an amount that is less than four times the pore volume of the support material, more preferably less than three times, even more preferably less than two times; preferred ranges being from 1.1 times to 3.5 times range and most preferably in the 1.2 to 3 times range. In an  
10 alternative embodiment, the amount of liquid in which the activator is present is from one to less than one times the pore volume of the support material utilized in forming the supported activator.

- [0093] Procedures for measuring the total pore volume of a porous support are well known in the art. Details of one of these procedures is discussed in Volume 1, *Experimental*  
15 *Methods in Catalytic Research* (Academic Press, 1968) (specifically see pages 67-96). This preferred procedure involves the use of a classical BET apparatus for nitrogen absorption. Another method well known in the art is described in Innes, *Total Porosity and Particle Density of Fluid Catalysts By Liquid Titration*, Vol. 28, No. 3, Analytical Chemistry 332-334 (March, 1956).

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#### **Polymerization Process**

- [0094] The activators of the invention, catalyst systems and supported catalyst systems utilizing the activators described above are suitable for use in any prepolymerization and/or polymerization process over a wide range of temperatures and pressures. The temperatures  
25 may be in the range of from -60°C to about 280°C, preferably from 50°C to about 200°C. In another embodiment the polymerization temperature is above 0°C, above 50°C, above 80°C, above 100°C, above 150°C, or above 200°C. In one embodiment the pressures employed may be in the range from 1 atmosphere to about 500 atmospheres or higher.

- [0095] Polymerization processes include solution, gas phase, slurry phase and a high  
30 pressure process or a combination thereof. Particularly preferred is a gas phase or slurry phase polymerization of one or more olefin(s) at least one of which is ethylene or propylene.

[0096] In one embodiment, the process of the invention is directed toward a solution, high pressure, slurry or gas phase polymerization process of one or more olefin monomers

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having from 2 to 30 carbon atoms, preferably 2 to 12 carbon atoms, and more preferably 2 to 8 carbon atoms. The invention is particularly well suited to the polymerization of two or more olefin monomers of ethylene, propylene, butene-1, pentene-1, 4-methyl-pentene-1, hexene-1, octene-1 and decene-1.

5 [0097] Other monomers useful in the process of the invention include ethylenically unsaturated monomers, diolefins having 4 to 18 carbon atoms, conjugated or nonconjugated dienes, polyenes, vinyl monomers and cyclic olefins. Non-limiting monomers useful in the invention may include norbornene, norbornadiene, isobutylene, isoprene, vinylbenzocyclobutane, styrenes, alkyl substituted styrene, ethylidene norbornene, 10 dicyclopentadiene and cyclopentene.

[0098] In another embodiment of the process of the invention, a copolymer of ethylene is produced, where with ethylene, a comonomer having at least one alpha-olefin having from 4 to 15 carbon atoms, preferably from 4 to 12 carbon atoms, and most preferably from 4 to 8 carbon atoms, is polymerized in a gas phase process.

15 [0099] In another embodiment of the process of the invention, ethylene or propylene is polymerized with at least two different comonomers, optionally one of which may be a diene, to form a terpolymer.

[0100] In one embodiment, the invention is directed to a polymerization process, particularly a gas phase or slurry phase process, for polymerizing propylene alone or with 20 one or more other monomers including ethylene, and/or other olefins having from 4 to 12 carbon atoms.

[0101] Typically in a gas phase polymerization process a continuous cycle is employed where in one part of the cycle of a reactor system, a cycling gas stream, otherwise known as a recycle stream or fluidizing medium, is heated in the reactor by the 25 heat of polymerization. This heat is removed from the recycle composition in another part of the cycle by a cooling system external to the reactor. Generally, in a gas fluidized bed process for producing polymers, a gaseous stream containing one or more monomers is continuously cycled through a fluidized bed in the presence of a catalyst under reactive conditions. The gaseous stream is withdrawn from the fluidized bed and recycled back 30 into the reactor. Simultaneously, polymer product is withdrawn from the reactor and fresh monomer is added to replace the polymerized monomer. (See for example U.S. Patent Nos. 4,543,399, 4,588,790, 5,028,670, 5,317,036, 5,352,749, 5,405,922, 5,436,304, 5,453,471, 5,462,999, 5,616,661 and 5,668,228).

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[0102] The reactor pressure in a gas phase process may vary from about 100 psig (690 kPa) to about 500 psig (3448 kPa), preferably in the range of from about 200 psig (1379 kPa) to about 400 psig (2759 kPa), more preferably in the range of from about 250 psig (1724 kPa) to about 350 psig (2414 kPa).

5 [0103] The reactor temperature in a gas phase process may vary from about 30°C to about 120°C, preferably from about 60°C to about 115°C, more preferably in the range of from about 70°C to 110°C, and most preferably in the range of from about 70°C to about 95°C. In another embodiment, the reactor temperature in a gas phase process is above 60°C.

10 [0104] Other gas phase processes contemplated by the process of the invention include series or multistage polymerization processes. Also gas phase processes contemplated by the invention include those described in U.S. Patent Nos. 5,627,242, 5,665,818 and 5,677,375, and European publications EP-A- 0 794 200 EP-B1-0 649 992, EP-A- 0 802 202 and EP-B- 634 421.

15 [0105] In another embodiment, the reactor utilized in the present invention is capable and the process of the invention is producing greater than 500 lbs of polymer per hour (227 Kg/hr) to about 200,000 lbs/hr (90,900 Kg/hr) or higher of polymer, preferably greater than 1000 lbs/hr (455 Kg/hr), more preferably greater than 10,000 lbs/hr (4540 Kg/hr), even more preferably greater than 25,000 lbs/hr (11,300 Kg/hr), still more  
20 preferably greater than 35,000 lbs/hr (15,900 Kg/hr), still even more preferably greater than 50,000 lbs/hr (22,700 Kg/hr) and most preferably greater than 65,000 lbs/hr (29,000 Kg/hr) to greater than 100,000 lbs/hr (45,500 Kg/hr).

[0106] A slurry polymerization process generally uses pressures in the range of from about 1 to about 50 atmospheres and even greater and temperatures in the range of 0°  
25 C to about 120°C. In another embodiment, the slurry process temperature is above 100°C. In a slurry polymerization, a suspension of solid, particulate polymer is formed in a liquid polymerization diluent medium to which ethylene and comonomers and often hydrogen along with catalyst are added. The suspension including diluent is intermittently or continuously removed from the reactor where the volatile components are separated from  
30 the polymer and recycled, optionally after a distillation, to the reactor. The liquid diluent employed in the polymerization medium is typically an alkane having from 3 to 7 carbon

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atoms, preferably a branched alkane. The medium employed should be liquid under the conditions of polymerization and relatively inert. When a propane medium is used the process must be operated above the reaction diluent critical temperature and pressure. Preferably, a hexane or an isobutane medium is employed.

5   **[0107]**        In another embodiment, the polymerization technique of the invention is referred to as a particle form polymerization, or a slurry process where the temperature is kept below the temperature at which the polymer goes into solution. Such technique is well known in the art, and described in for instance U.S. Patent No. 3,248,179. Other slurry processes include those employing a loop reactor and those utilizing a plurality of  
10   stirred reactors in series, parallel, or combinations thereof. Non-limiting examples of slurry processes include continuous loop or stirred tank processes. Also, other examples of slurry processes are described in U.S. Patent No. 4,613,484.

**[0108]**        In another embodiment the reactor used in the slurry process of the invention is capable of and the process of the invention is producing greater than 2000 lbs  
15   of polymer per hour (907 Kg/hr), more preferably greater than 5000 lbs/hr (2268 Kg/hr), and most preferably greater than 10,000 lbs/hr (4540 Kg/hr). In another embodiment the slurry reactor used in the process of the invention is producing greater than 15,000 lbs of polymer per hour (6804 Kg/hr), preferably greater than 25,000 lbs/hr (11,340 Kg/hr) to about 100,000 lbs/hr (45,500 Kg/hr).

20   **[0109]**        Examples of solution processes are described in U.S. Patent Nos. 4,271,060, 5,001,205, 5,236,998 and 5,589,555 and PCT WO 99/32525.

**[0110]**        In one embodiment of the process of the invention is the process, preferably a slurry or gas phase process is operated in the presence of the catalyst system of the invention and in the absence of or essentially free of any scavengers, such as  
25   triethylaluminum, trimethylaluminum, tri-isobutylaluminum and tri-n-hexylaluminum and diethyl aluminum chloride, dibutyl zinc and the like. This process is described in PCT publication WO 96/08520 and U.S. Patent No. 5,712,352 and 5,763,543.

**[0111]**        In another embodiment, the method of the invention provides for injecting the catalyst system of the invention into a reactor, particularly a gas phase reactor. In one  
30   embodiment the catalyst system is used in the unsupported form, preferably in a liquid form such as described in U.S. Patent Nos. 5,317,036 and 5,693,727 and European

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publication EP-A-0 593 083. The polymerization catalyst in liquid form can be fed with an activator, and/or a support, and/or a supported activator together or separately to a reactor. The injection methods described in PCT publication WO 97/46599, may be utilized. Where an unsupported catalyst system is used the mole ratio of the metal of the

5 Lewis acid activator component to the metal of the phenoxide transition metal catalyst compound is in the range of between 0.3:1 to 10,000:1, preferably 100:1 to 5000:1, and most preferably 500:1 to 2000:1.

#### **Polymer Products**

10 **[0112]** The polymers produced by the process of the invention can be used in a wide variety of products and end-use applications. The polymers produced include linear low density polyethylene, elastomers, plastomers, high density polyethylenes, medium density polyethylenes, low density polyethylenes, polypropylene and polypropylene copolymers.

15 **[0113]** The polymers, typically ethylene based polymers, have a density in the range of from 0.86g/cc to 0.97 g/cc, preferably in the range of from 0.88 g/cc to 0.965 g/cc, more preferably in the range of from 0.900 g/cc to 0.96 g/cc, even more preferably in the range of from 0.905 g/cc to 0.95 g/cc, yet even more preferably in the range from 0.910 g/cc to 0.940 g/cc, and most preferably greater than 0.915 g/cc, preferably greater

20 than 0.920 g/cc, and most preferably greater than 0.925 g/cc. Density is measured in accordance with ASTM-D-1238.

**[0114]** The polymers produced by the process of the invention typically have a molecular weight distribution, a weight average molecular weight to number average molecular weight ( $M_w/M_n$ ) of greater than 1.5 to about 15, particularly greater than 2 to

25 about 10, more preferably greater than about 2.2 to less than about 8, and most preferably from 2.5 to 8.

**[0115]** Also, the polymers of the invention typically have a narrow composition distribution as measured by Composition Distribution Breadth Index (CDBI). Further details of determining the CDBI of a copolymer are known to those skilled in the art. See,

30 for example, PCT Patent Application WO 93/03093, published February 18, 1993. The polymers of the invention in one embodiment have CDBI's generally in the range of



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greater than 50% to 100%, preferably 99%, preferably in the range of 55% to 85%, and more preferably 60% to 80%, even more preferably greater than 60%, still even more preferably greater than 65%.

**[0116]** In another embodiment, polymers produced using a catalyst system of the invention have a CDBI less than 50%, more preferably less than 40%, and most preferably less than 30%.

**[0117]** The polymers of the present invention in one embodiment have a melt index (MI) or ( $I_2$ ) as measured by ASTM-D-1238-E in the range from no measurable flow to 1000 dg/min, more preferably from about 0.01 dg/min to about 100 dg/min, even more preferably from about 0.1 dg/min to about 50 dg/min, and most preferably from about 0.1 dg/min to about 10 dg/min.

**[0118]** The polymers of the invention in an embodiment have a melt index ratio ( $I_{21}/I_2$ ) ( $I_{21}$  is measured by ASTM-D-1238-F) of from 10 to less than 25, more preferably from about 15 to less than 25.

**[0119]** The polymers of the invention in a preferred embodiment have a melt index ratio ( $I_{21}/I_2$ ) ( $I_{21}$  is measured by ASTM-D-1238-F) of from preferably greater than 25, more preferably greater than 30, even more preferably greater than 40, still even more preferably greater than 50 and most preferably greater than 65. In an embodiment, the polymer of the invention may have a narrow molecular weight distribution and a broad composition distribution or vice-versa, and may be those polymers described in U.S. Patent No. 5,798,427.

**[0120]** In yet another embodiment, propylene based polymers are produced in the process of the invention. These polymers include atactic polypropylene, isotactic polypropylene, hemi-isotactic and syndiotactic polypropylene. Other propylene polymers include propylene block or impact copolymers. Propylene polymers of these types are well known in the art see for example U.S. Patent Nos. 4,794,096, 3,248,455, 4,376,851, 5,036,034 and 5,459,117.

**[0121]** The polymers of the invention may be blended and/or coextruded with any other polymer. Non-limiting examples of other polymers include linear low density polyethylenes, elastomers, plastomers, high pressure low density polyethylene, high density polyethylenes, polypropylenes and the like.

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[0122] Polymers produced by the process of the invention and blends thereof are useful in such forming operations as film, sheet, and fiber extrusion and co-extrusion as well as blow molding, injection molding and rotary molding. Films include blown or cast films formed by coextrusion or by lamination useful as shrink film, cling film, stretch film, 5 sealing films, oriented films, snack packaging, heavy duty bags, grocery sacks, baked and frozen food packaging, medical packaging, industrial liners, membranes, etc. in food-contact and non-food contact applications. Fibers include melt spinning, solution spinning and melt blown fiber operations for use in woven or non-woven form to make filters, diaper fabrics, medical garments, geotextiles, etc. Extruded articles include medical 10 tubing, wire and cable coatings, pipe, geomembranes, and pond liners. Molded articles include single and multi-layered constructions in the form of bottles, tanks, large hollow articles, rigid food containers and toys, etc.

#### **EXAMPLES**

15 [0123] In order to provide a better understanding of the present invention including representative advantages thereof, the following examples are offered.

#### **COMPARATIVE EXAMPLE 1.**

[0124] Silica supported  $(1,3\text{-MeBuCp})_2\text{ZrCl}_2$ , activated with MAO, was prepared 20 in accordance with the method outlined in U.S. Patent No. 5,712,352.

#### **EXAMPLE 2.**

[0125] 0.07 grams of triethylaluminum in toluene were combined with 1.0 grams of silica (Davison 948 calcined at 600°C, 2 wt%F) in a 100 flask. The resulting slurry was 25 allowed to sit overnight. The silica was then filtered, and rinsed with several 10 ml portions of toluene. 0.10 grams of 4,5,6,7-tetrafluoroindole was added to the silica, slurried in toluene and heated to 100°C for 1.5 hours. The silica was then filtered, rinsed with several 10 ml portions of toluene, and subsequently combined with 0.09 grams of a 20 wt % solution of  $(1,3\text{-Me,BuCp})_2\text{ZrMe}_2$  in toluene. The supported catalyst was 30 allowed to sit at room temperature for 1 hr. The catalyst was filtered, rinsed with several 10 ml portions of toluene, and dried under a vacuum.

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**EXAMPLE 3.**

**[0126]** 0.08 grams of triethylaluminum in toluene were combined with 1.0 grams of silica (Davison 948 calcined at 200°C) in a 100 flask. The resulting slurry was allowed to sit overnight. The silica was then filtered, and rinsed with several 10 ml portions of toluene. 0.10 grams of 4,5,6,7-tetrafluoroindole was added to silica, slurried in toluene and heated to 100°C for 1.5 hours. The silica was then filtered, rinsed with several 10 ml portions of toluene, and subsequently combined with 0.09 grams of a 20 wt % solution of (1,3-Me,BuCp)<sub>2</sub>ZrMe<sub>2</sub> in toluene. The supported catalyst was allowed to sit at room temperature for 1 hr. The catalyst was filtered, rinsed with several 10 ml portions of toluene, and dried under a vacuum.

**EXAMPLE 4.**

**[0127]** 0.08 grams of triethylaluminum in toluene were combined with 1.0 grams of silica (Davison 948 calcined at 200°C) in a 100 flask. The resulting slurry was allowed to sit overnight. The resulting silica was filtered, and rinsed with several 10 ml portions of toluene. 0.090 grams of 4,5,6,7-tetrafluoroindole was added to silica, slurried in *o*-xylene and heated to 140°C for 1.5 hours. The silica was then filtered, rinsed with several 10 ml portions of toluene, and subsequently combined with 0.09 grams of a 20 wt % solution of (1,3-Me,BuCp)<sub>2</sub>ZrMe<sub>2</sub> in toluene. The supported catalyst was allowed to sit at room temperature for 1 hr. The catalyst was filtered, rinsed with several 10 ml portions of toluene, and dried under a vacuum.

**EXAMPLE 5.**

**[0128]** In a 100 ml r.b. flask, 200 mg of tetraethylaluminoxane (1.0 M in toluene) was dissolved in 30 ml of toluene. To this solution, 1.00 g. of silica (Davison 948 calcined at 200°C) was added. This slurry was allowed to stand overnight at room temperature. The slurry was filtered through a frit, washed with toluene (3 x 10 ml) and partially dried under vacuum. In a dried 100 ml r.b. flask, 400 mg of 4,5,6,7-tetrafluoroindole was dissolved in 30 ml of *o*-xylene. The partially dried silica was transferred to the flask and slurried. An immediate, noticeable color change was observed from the off-white silica to a yellow-tinted slurry. The flask was placed in an oil bath at 135°C for three hours and

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stirred every half-hour. Over the three hour period, the color of the slurry darkened to an orange and finally a dark orange/brown hue. The flask was removed from the oil bath and allowed to cool to room temperature. The slurry was then filtered, washed with toluene and partially dried under vacuum. In a dried 100 ml r.b. flask, 100 mg of a 20 wt % solution of (1,3-Me,BuCp)<sub>2</sub>ZrMe<sub>2</sub> in toluene was dissolved in 30 ml of toluene. The partially dried silica was transferred into the flask and the slurry was allowed to stand overnight at room temperature. The slurry was filtered through a frit and dried thoroughly under vacuum.

10 **EXAMPLE 6.**

[0129] In a 100 ml r.b. flask, 200 mg of 4,5,6,7-tetrafluoroindole was dissolved in 30 ml of *o*-xylene. To this solution, 1.00 g. of TEAL-treated silica (Davison 948 calcined at 600°C) was added. An immediate, noticeable color change was observed from the off-white silica to a yellow-tinted slurry. The flask was placed in an oil bath at 135°C for three hours and stirred every half-hour. Over the three hour period, the color of the slurry darkened to an orange and finally a dark orange/brown hue. The flask was removed from the oil bath and allowed to cool to room temperature. The slurry was then filtered, washed with toluene and partially dried under vacuum. In a dried 100 ml r.b. flask, 100 mg of a 20 wt % solution of (1,3-Me,BuCp)<sub>2</sub>ZrMe<sub>2</sub> in toluene was dissolved in 30 ml of toluene. The partially dried silica was transferred into the flask and the slurry was allowed to stand overnight at room temperature. The slurry was filtered through a frit and dried thoroughly under vacuum.

**EXAMPLE 7.**

25 [0130] 0.16 grams of triethylaluminum in toluene were combined with 1.0 grams of silica (Davison 948 calcined at 600°C) in a 100 flask. The resulting slurry was allowed to sit overnight. The resulting silica was filtered, and rinsed with several 10 ml portions of toluene. 0.05 grams of 4,5,6,7-tetrafluoroindole was added to silica, slurried in *o*-xylene and heated to 140°C for three hours. Over the three hour period, the color of the slurry darkened to an orange and finally a dark orange/brown hue. The silica was then filtered, rinsed with several 10 ml portions of toluene, and subsequently combined with 0.09 grams

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of a 20 wt % solution of  $(1,3\text{-Me,BuCp})_2\text{ZrMe}_2$  in toluene. The supported catalyst was allowed to sit at room temperature for 1 hr. The catalyst was filtered, rinsed with several 10 ml portions of toluene, and dried under a vacuum.

5 **EXAMPLE 8.**

[0131] 0.16 grams of triethylaluminum in toluene were combined with 1.0 grams of silica (Davison 948 calcined at 600°C) in a 100 flask. The resulting slurry was allowed to sit overnight. The resulting silica was filtered, and rinsed with several 10 ml portions of toluene. 0.2 grams of 4,5,6,7-tetrafluoroindole was added to silica, slurried in *o*-xylene  
10 and heated to 140°C for three hours. The silica was then filtered, rinsed with several 10 ml portions of toluene, and subsequently combined with 0.09 grams of a 20 wt % solution of  $(1,3\text{-Me,BuCp})_2\text{ZrMe}_2$  in toluene. The supported catalyst was allowed to sit at room temperature for 1 hr. The catalyst was filtered, rinsed with several 10 ml portions of toluene, and dried under a vacuum.

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**EXAMPLE 9.**

[0132] In a 100 ml r.b. flask, 100 mg of triethylaluminum was dissolved in 30 ml of toluene. To this solution, 1.00 g. of silica (Davison 948 calcined at 300°C) was added. This slurry was allowed to stand overnight at room temperature. The slurry was filtered  
20 through a frit, washed with toluene (3 x 10 ml) and partially dried under vacuum. In a dried 100 ml r.b. flask, 200 mg of 4,5,6,7-tetrafluoroindole was dissolved in 30 ml of *o*-xylene. The partially dried silica was transferred to the flask and slurried. An immediate, noticeable color change was observed from the off-white silica to a yellow-tinted slurry. The flask was placed in an oil bath at 140°C for three hours and stirred every half-hour.  
25 Over the three hour period, the color of the slurry darkened to an orange and finally a dark orange/brown hue. The flask was removed from the oil bath and allowed to cool to room temperature. The slurry was then filtered, washed with toluene and partially dried under vacuum. In a dried 100 ml r.b. flask, 100 mg of of a 20 wt % solution of  $(1,3\text{-Me,BuCp})_2\text{ZrMe}_2$  in toluene was dissolved in 30 ml of toluene. The partially dried silica  
30 was transferred into the flask and the slurry was allowed to stand overnight at room temperature. The slurry was filtered through a frit and dried thoroughly under vacuum.

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**EXAMPLE 10.**

**[0133]** In a 100 ml r.b. flask, 250 mg of triethylaluminum was dissolved in 30 ml of toluene. To this solution, 1.00 g. of silica (Davison 948 calcined at 200°C) was added. This slurry was allowed to stand overnight at room temperature. The slurry was filtered through a frit, washed with toluene (3 x 10 ml) and partially dried under vacuum. In a dried 100 ml r.b. flask, 200 mg of 4,5,6,7-tetrafluoroindole was dissolved in 30 ml of *o*-xylene. The partially dried silica was transferred to the flask and slurried. An immediate, noticeable color change was observed from the off-white silica to a yellow-tinted slurry. The flask was placed in an oil bath at 140°C for three hours and stirred every half-hour. Over the three hour period, the color of the slurry darkened to an orange and finally a dark orange/brown hue. The flask was removed from the oil bath and allowed to cool to room temperature. The slurry was then filtered, washed with toluene and partially dried under vacuum. In a dried 100 ml r.b. flask, 100 mg of a 20 wt % solution of (1,3-Me,BuCp)<sub>2</sub>ZrMe<sub>2</sub> in toluene was dissolved in 30 ml of toluene. The partially dried silica was transferred into the flask and the slurry was allowed to stand overnight at room temperature. The slurry was filtered through a frit and dried thoroughly under vacuum.

**EXAMPLE 11.**

**[0134]** In a 100 ml r.b. flask, 250 mg of triethylaluminum was dissolved in 30 ml of toluene. To this solution, 1.00 g. of silica (948 calcined at 300°C) was added. This slurry was allowed to stand overnight at room temperature. The slurry was filtered through a frit, washed with toluene (3 x 10 ml) and partially dried under vacuum. In a dried 100 ml r.b. flask, 200 mg of 4,5,6,7-tetrafluoroindole was dissolved in 30 ml of *o*-xylene. The partially dried silica was transferred to the flask and slurried. An immediate, noticeable color change was observed from the off-white silica to a yellow-tinted slurry. The flask was placed in an oil bath at 140°C for three hours and stirred every half-hour. Over the three hour period, the color of the slurry darkened to an orange and finally a dark orange/brown hue. The flask was removed from the oil bath and allowed to cool to room temperature. The slurry was then filtered, washed with toluene and partially dried under vacuum. In a dried 100 ml r.b. flask, 100 mg of a 20 wt % solution of (1,3-Me,BuCp)<sub>2</sub>ZrMe<sub>2</sub> in toluene was dissolved in 30 ml of toluene. The partially dried silica

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was transferred into the flask and the slurry was allowed to stand overnight at room temperature. The slurry was filtered through a frit and dried thoroughly under vacuum.

**EXAMPLE 12.**

5 [0135] 0.07 grams of triethylaluminum in toluene were combined with 1.0 grams of silica (Davison 948 600°C) in a 100 flask. The resulting slurry was allowed to sit overnight. The resulting silica was filtered, and rinsed with several 10 ml portions of toluene. 0.2 grams of 4,5,6,7-tetrafluoroindole was added to silica, slurried in o-xylene and heated to 140°C for 1.5 hours. Over the 1.5 hour period, the color of the slurry  
10 darkened to an orange and finally a dark orange/brown hue. The silica was then filtered, rinsed with several 10 ml portions of toluene, and subsequently combined with 0.09 grams of a 20 wt % solution of (1,3-Me,BuCp)<sub>2</sub>ZrMe<sub>2</sub> in toluene. The supported catalyst was allowed to sit at room temperature for 1 hr. The catalyst was filtered, rinsed with several 10 ml portions of toluene, and dried under a vacuum.

15

**EXAMPLE 13.**

[0136] 0.25 grams of triethylaluminum in toluene were combined with 1.0 grams of silica (Davison 948 200°C) in a 100 flask. The resulting slurry was allowed to sit overnight. The resulting silica was filtered, and rinsed with several 10 ml portions of  
20 toluene. 0.1 grams of 4,5,6,7-tetrafluoroindole was added to silica, slurried in o-xylene and heated to 140°C for three hours. Over the three hour period, the color of the slurry darkened to an orange and finally a dark orange/brown hue. The silica was then filtered, rinsed with several 10 ml portions of toluene, and subsequently combined with 0.09 grams of a 20 wt % solution of (1,3-Me,BuCp)<sub>2</sub>ZrMe<sub>2</sub> in toluene. The supported catalyst was  
25 allowed to sit at room temperature for 1 hr. The catalyst was filtered, rinsed with several 10 ml portions of toluene, and dried under a vacuum.

**EXAMPLE 14.**

[0137] 0.07 grams of triethylaluminum in toluene were combined with 1.0 grams  
30 of silica (Davison 948 600°C , 2 wt%F) in a 100 flask. The resulting slurry was allowed to sit overnight. The resulting silica was filtered, and rinsed with several 10 ml portions of

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toluene. 0.20 grams of 4,5,6,7-tetrafluoroindole was added to silica, slurried in toluene and heated to 100°C for 1.5 hours. Over the 1.5 hour period, the color of the slurry darkened to an orange and finally a dark orange/brown hue. The silica was then filtered, rinsed with several 10 ml portions of toluene, and subsequently combined with 0.09 grams of a 20 wt % solution of (1,3-Me,BuCp)<sub>2</sub>ZrMe<sub>2</sub> in toluene. The supported catalyst was allowed to sit at room temperature for 1 hr. The catalyst was filtered, rinsed with several 10 ml portions of toluene, and dried under a vacuum.

**EXAMPLE 15.**

[0138] 0.07 grams of triethylaluminum in toluene were combined with 1.0 grams of silica (Davison 948 600°C) in a 100 flask. The resulting slurry was allowed to sit overnight. The resulting silica was filtered, and rinsed with several 10 ml portions of toluene. 0.050 grams of 4,5,6,7-tetrafluoroindole was added to silica, slurried in o-xylene and heated to 140°C for 1.5 hours. Over the 1.5 hour period, the color of the slurry darkened to an orange and finally a dark orange/brown hue. The silica was then filtered, rinsed with several 10 ml portions of toluene, and subsequently combined with 0.09 grams of a 20 wt % solution of (1,3-Me,BuCp)<sub>2</sub>ZrMe<sub>2</sub> in toluene. The supported catalyst was allowed to sit at room temperature for 1 hr. The catalyst was filtered, rinsed with several 10 ml portions of toluene, and dried under a vacuum.

**EXAMPLE 16.**

[0139] In a 100 ml r.b. flask, 200 mg of tetraethylaluminoxane (1.0 M in toluene) was dissolved in 30 ml of toluene. To this solution, 1.00 g. of silica (948 calcined at 300°C) was added. This slurry was allowed to stand overnight at room temperature. The slurry was filtered through a frit, washed with toluene (3 x 10 ml) and partially dried under vacuum. In a dried 100 ml r.b. flask, 200 mg of 4,5,6,7-tetrafluoroindole was dissolved in 30 ml of o-xylene. The partially dried silica was transferred to the flask and slurried. An immediate, noticeable color change was observed from the off-white silica to a yellow-tinted slurry. The flask was placed in an oil bath at 140°C for three hours and stirred every half-hour. Over the three hour period, the color of the slurry darkened to an orange and finally a dark orange/brown hue. The flask was removed from the oil bath and allowed to



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cool to room temperature. The slurry was then filtered, washed with toluene and partially dried under vacuum. In a dried 100 ml r.b. flask, 100mg of a 20 wt % solution of (1,3-Me,BuCp)<sub>2</sub>ZrMe<sub>2</sub> in toluene was dissolved in 30 ml of toluene. The partially dried silica was transferred into the flask and the slurry was allowed to stand overnight at room  
5 temperature. The slurry was filtered through a frit and dried thoroughly under vacuum.

### Polymerizations

**[0140]** Polymerizations utilizing the supported catalyst systems prepared in Examples 1-16 were performed in a glass-lined 20-milliliter autoclave reactor equipped  
10 with a mechanical stirrer, an external heater for temperature control, a septum inlet and a regulated supply of dry nitrogen and ethylene in an inert atmosphere (Nitrogen) glove box. The reactor was dried and degassed thoroughly at 115 °C. The diluent, comonomer, and scavenger (if used), were added at room temperature and atmospheric pressure. The reactor was then brought to process pressure and charged with ethylene while stirring at  
15 800 RPM. The activator and catalyst were added via syringe with the reactor at process conditions. The polymerization was continued while maintaining the reaction vessel within 3 °C of the target process temperature and 5 psig of target process pressure (by automatic addition of ethylene on demand) until a fixed uptake of ethylene was noted (corresponding to ca. 0.15 g polymer) or until a maximum reaction time of 40 minutes had  
20 passed. The reaction was stopped by pressurizing the reactor to 30 psig above the target process pressure with a gas mixture composed of 5 mol% Oxygen in Argon. The polymer was recovered by vacuum centrifugation of the reaction mixture. Bulk polymerization activity was calculated by dividing the yield of polymer by the total weight of the catalyst charge by the time in hours and by the absolute monomer pressure in atmospheres. The  
25 specific polymerization activity was calculated by dividing the yield of polymer by the total number of millimoles of transition metal contained in the catalyst charge by the time in hours and by the absolute monomer pressure in atmospheres. Pertinent data, for the polymers prepared by the catalyst systems of Examples 1-16, is summarized in Table 1.

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TABLE 1. Polymerization Data Utilizing Catalyst Systems of Examples 1-16

Example	Comonomer Incorporation	Average Mw	Average Mn	Average PDI	Yield g	Activity (gpol./gcat.*hr)	
Comp. 1	3.2	384294.4	210524	1.8	0.126	540.4	
Comp. 1	3	388432.4	182978	2.1	0.121	581.4	
Comp. 1	2.7	387380.3	193085	2.0	0.127	588.0	
	average	3.0	386702	195529	2.0	0.125	569.9
	stddev	0.3	2151	13935	0.2	0.003	25.8
2	2.4	488364.2	294861	1.7	0.096	213.3	
2	2.5	473494.7	197664	2.4	0.106	235.5	
2	2.8	460380.8	200747	2.3	0.089	197.7	
	average	2.6	474080	231091	2.1	0.097	215.5
	stddev	0.2	14001	55249	0.4	0.009	19.0
3	2.7	492415.7	279347	1.8	0.108	240.0	
3	2.3	497942.3	293455	1.7	0.085	188.8	
3	2.5	483749.5	234490	2.1	0.097	215.5	
	average	2.5	491369	269097	1.9	0.097	214.8
	stddev	0.2	7154	30789	0.2	0.012	25.6
4	2.4	505596.9	270467	1.9	0.071	157.7	
4	2.5	495952	289348	1.7	0.07	155.5	
4	2.5	502853.1	308021	1.6	0.068	151.1	
	average	2.5	501467	289279	1.7	0.070	154.8
	stddev	0.1	4970	18777	0.2	0.002	3.4
5	2.6	534594.8	261170	2	0.034	75.5	
5	2.4	529599.8	319500	1.7	0.033	73.3	
5	2.4	533958.8	323033	1.7	0.033	73.3	
	average	2.5	532718	301234	1.8	0.033	74.1
	stddev	0.1	2719	34741	0.2	0.001	1.3
6	2.4	413283.6	249554	1.7	0.126	518.7	
6	2.7	428413.4	250426	1.7	0.121	386.1	
6	2.8	427108	180713	2.4	0.118	394.8	
	average	2.6	422935	226898	1.9	0.122	433.2
	stddev	0.2	8384	39999	0.4	0.004	74.2
7	2.6	450490	253608	1.8	0.109	242.2	
7	2.6	473306.2	216051	2.2	0.092	204.4	
7	2.7	460814.3	277469	1.7	0.104	231.0	
	average	2.6	461537	249043	1.9	0.102	225.9
	stddev	0.1	11425	30962	0.3	0.009	19.4

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TABLE 1 (continued). Polymerization Data Utilizing Catalyst Systems of Examples 1-16

Example		Comonomer Incorporation	I-10		Average PDI	Yield g	Activity (gpol./gcat.*hr)
			Average Mw	Average Mn			
8		2.7	412245.7	230767	1.8	0.12	489.4
8		2.8	425803	253212	1.7	0.13	452.2
8		2.9	435136.5	245094	1.8	0.124	483.5
	average	2.8	424395	243024	1.8	0.119	475.1
	stddev	0.1	11510	11365	0.1	0.006	20.0
9		2.6	416014.3	227484	1.8	0.118	747.5
9		2.7	426636.9	256396	1.7	0.121	709.4
9		2.6	412179.3	258209	1.6	0.123	635.1
	average	2.6	418277	247363	1.7	0.121	697.3
	stddev	0.1	7490	17240	0.1	0.003	57.2
10		3	368421.1	158260	2.3	0.136	1175.2
10		3.2	368194.5	152915	2.4	0.134	1082.2
10		3.1	375514.8	208971	1.8	0.136	1091.1
	average	3.1	370710	173382	2.2	0.135	1116.1
	stddev	0.1	4163	30936	0.3	0.001	51.3
11		2.9	371230.9	219215	1.7	0.134	928.9
11		2.9	373737.8	178173	2.1	0.126	763.7
11		2.7	384209.4	95935.8	4	0.125	697.7
	average	2.8	376393	164441	2.6	0.128	796.8
	stddev	0.1	6885	62776	1.2	0.005	119.1
12		2.5	452255.5	273513	1.7	0.12	312.3
12		2.4	459286.3	280637	1.6	0.118	317.4
12		2.4	454071.4	253811	1.8	0.121	320.4
	average	2.4	455204	269320	1.7	0.120	316.7
	stddev	0.1	3650	13896	0.1	0.002	4.1
13		2.9	389071.4	224975	1.7	0.126	759.8
13		2.8	407174.1	240628	1.7	0.127	769.9
13		2.7	402496.9	244037	1.6	0.125	777.9
	average	2.8	399581	236547	1.7	0.126	769.2
	stddev	0.1	9397	10165	0.1	0.001	9.1
14		2.6	569861.2	306875	1.9	0.03	66.6
14		2	604007.1	297091	2	0.028	62.2
14		1.6	603578	372672	1.6	0.03	66.7
	average	2.1	592482	325546	1.8	0.029	65.2
	stddev	0.5	19591	41104	0.2	0.001	2.6
15		2.7	498835.6	295027	1.7	0.051	113.3

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**TABLE 1 (continued). Polymerization Data Utilizing Catalyst Systems of Examples 1-16**

Example	Comonomer Incorporation	Average Mw	Average Mn	Average PDI	Yield g	Activity (gpol./gcat.*hr)
15	2.4	517815.5	310117	1.7	0.049	108.9
15	2.8	493251.1	251626	2	0.048	106.6
	average	503301	285590	1.8	0.049	109.6
	stddev	12877	30366	0.2	0.002	3.4
16	2.6	449126.6	266821	1.7	0.059	131.1
16	2.8	450262.2	262548	1.7	0.058	128.9
16	2.6	461867.4	278393	1.7	0.051	113.3
	average	453752	269254	1.7	0.056	124.4
	stddev	7051	8198	0.0	0.004	9.7

5

**EXAMPLE 17.**

**[0141]** 10.0 grams of triethylaluminum in toluene were combined with 40.0 grams of silica (Davison 948 200°C) in a 100 flask. The resulting slurry was allowed to sit overnight. The resulting silica was filtered, and rinsed with several 100 ml portions of toluene. 4.0 grams of 4,5,6,7-tetrafluoroindole was added to silica, slurried in o-xylene and heated to 140°C for three hours. Over the three hour period, the color of the slurry darkened to an orange and finally a dark orange/brown hue. The silica was then filtered, rinsed with several 100 ml portions of toluene, and dried under vacuum. 36.0 grams of the support was combined with 2.7 grams of a 20 wt % solution of (1,3-Me,BuCp)<sub>2</sub>ZrMe<sub>2</sub> in toluene. The supported catalyst was allowed to sit at room temperature for 1 hr. The catalyst was filtered, rinsed with several 100 ml portions of toluene, and dried under a vacuum.

**EXAMPLE 18.**

**[0142]** In a 100 ml r.b. flask, 250 mg of triisobutylaluminum was dissolved in 30 ml of toluene. To this solution, 1.00 g. of silica (948 calcined at 300°C) was added. This slurry was allowed to stand overnight at room temperature. The slurry was filtered through a frit, washed with toluene (3 x 10 ml) and partially dried under vacuum. In a dried 100 ml r.b. flask, 100 mg of 4,5,6,7-tetrafluoroindole was dissolved in 30 ml of o-xylene. The partially dried silica was transferred to the flask and slurried. An immediate,

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noticeable color change was observed from the off-white silica to a yellow-tinted slurry. The flask was placed in an oil bath at 140°C for three hours and stirred every half-hour. Over the three hour period, the color of the slurry darkened to an orange and finally a dark orange/brown hue. The flask was removed from the oil bath and allowed to cool to room temperature. The slurry was then filtered, washed with toluene and partially dried under vacuum. In a dried 100 ml r.b. flask, 100 mg of a 20 wt % solution of (1,3-Me,BuCp)<sub>2</sub>ZrMe<sub>2</sub> in toluene was dissolved in 30 ml of toluene. The partially dried silica was transferred into the flask and the slurry was allowed to stand overnight at room temperature. The slurry was filtered through a frit and dried thoroughly under vacuum.

**EXAMPLE 19.**

[0143] In a 100 ml r.b. flask, 250 mg of triethylaluminum was dissolved in 30 ml of toluene. To this solution, 1.00 g. of silica (948 calcined at 200°C) was added. This slurry was allowed to stand overnight at room temperature. The slurry was filtered through a frit, washed with toluene (3 x 10 ml) and partially dried under vacuum. In a dried 100 ml r.b. flask, 200 mg of 5-fluoroindole was dissolved in 30 ml of *o*-xylene. The partially dried silica was transferred to the flask and slurried. An immediate, noticeable color change was observed from the off-white silica to a yellow-tinted slurry. The flask was placed in an oil bath at 140°C for three hours and stirred every half-hour. Over the three hour period, the color of the slurry darkened to an orange and finally a dark orange/brown hue. The flask was removed from the oil bath and allowed to cool to room temperature. The slurry was then filtered, washed with toluene and partially dried under vacuum. In a dried 100 ml r.b. flask, 100 mg of a 20 wt % solution of (1,3-Me,BuCp)<sub>2</sub>ZrMe<sub>2</sub> in toluene was dissolved in 30 ml of toluene. The partially dried silica was transferred into the flask and the slurry was allowed to stand overnight at room temperature. The slurry was filtered through a frit and dried thoroughly under vacuum.

**EXAMPLE 20.**

[0144] In a 100 ml r.b. flask, 250 mg of triisobutylaluminum was dissolved in 30 ml of toluene. To this solution, 1.00 g. of silica (948 calcined at 200°C) was added. This slurry was allowed to stand overnight at room temperature. The slurry was filtered

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through a frit, washed with toluene (3 x 10 ml) and partially dried under vacuum. In a dried 100 ml r.b. flask, 200 mg of 4,5,6,7-tetrafluoroindole was dissolved in 30 ml of *o*-xylene. The partially dried silica was transferred to the flask and slurried. An immediate, noticeable color change was observed from the off-white silica to a yellow-tinted slurry.

- 5 The flask was placed in an oil bath at 140°C for three hours and stirred every half-hour. Over the three hour period, the color of the slurry darkened to an orange and finally a dark orange/brown hue. The flask was removed from the oil bath and allowed to cool to room temperature. The slurry was then filtered, washed with toluene and partially dried under vacuum. In a dried 100 ml r.b. flask, 100 mg of a 20 wt % solution of (1,3-
- 10 Me,BuCp)<sub>2</sub>ZrMe<sub>2</sub> in toluene was dissolved in 30 ml of toluene. The partially dried silica was transferred into the flask and the slurry was allowed to stand overnight at room temperature. The slurry was filtered through a frit and dried thoroughly under vacuum.

#### EXAMPLE 21.

- 15 **[0145]** In a 100 ml r.b. flask, 250 mg of triisobutylaluminum was dissolved in 30 ml of toluene. To this solution, 1.00 g. of silica (948 calcined at 200°C) was added. This slurry was allowed to stand overnight at room temperature. The slurry was filtered through a frit, washed with toluene (3 x 10 ml) and partially dried under vacuum. In a dried 100 ml r.b. flask, 100 mg of 4,5,6,7-tetrafluoroindole was dissolved in 30 ml of *o*-
- 20 xylene. The partially dried silica was transferred to the flask and slurried. An immediate, noticeable color change was observed from the off-white silica to a yellow-tinted slurry. The flask was placed in an oil bath at 140°C for three hours and stirred every half-hour. Over the three hour period, the color of the slurry darkened to an orange and finally a dark orange/brown hue. The flask was removed from the oil bath and allowed to cool to room
- 25 temperature. The slurry was then filtered, washed with toluene and partially dried under vacuum. In a dried 100 ml r.b. flask, 100 mg of a 20 wt % solution of (1,3-Me,BuCp)<sub>2</sub>ZrMe<sub>2</sub> in toluene was dissolved in 30 ml of toluene. The partially dried silica was transferred into the flask and the slurry was allowed to stand overnight at room temperature. The slurry was filtered through a frit and dried thoroughly under vacuum.

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**EXAMPLE 22.**

**[0146]** In a 100 ml r.b. flask, 250 mg of triisobutylaluminum was dissolved in 30 ml of toluene. To this solution, 1.00 g. of silica (948 calcined at 300°C) was added. This slurry was allowed to stand overnight at room temperature. The slurry was filtered  
5 through a frit, washed with toluene (3 x 10 ml) and partially dried under vacuum. In a dried 100 ml r.b. flask, 200 mg of 4,5,6,7-tetrafluoroindole was dissolved in 30 ml of *o*-xylene. The partially dried silica was transferred to the flask and slurried. An immediate, noticeable color change was observed from the off-white silica to a yellow-tinted slurry. The flask was placed in an oil bath at 140°C for three hours and stirred every half-hour.  
10 Over the three hour period, the color of the slurry darkened to an orange and finally a dark orange/brown hue. The flask was removed from the oil bath and allowed to cool to room temperature. The slurry was then filtered, washed with toluene and partially dried under vacuum. In a dried 100 ml r.b. flask, 100 mg of a 20 wt % solution of (1,3-Me,BuCp)<sub>2</sub>ZrMe<sub>2</sub> in toluene was dissolved in 30 ml of toluene. The partially dried silica  
15 was transferred into the flask and the slurry was allowed to stand overnight at room temperature. The slurry was filtered through a frit and dried thoroughly under vacuum.

**EXAMPLE 23.**

**[0147]** In a 100 ml r.b. flask, 200 mg of 4,5,6,7-tetrafluoroindole was dissolved in  
20 30 ml of *o*-xylene. To this solution, 1.00 g. of TEAL-treated silica (948 calcined at 600°C) was added. An immediate, noticeable color change was observed from the off-white silica to a yellow-tinted slurry. The flask was placed in an oil bath at 140°C for three hours and stirred every half-hour. Over the three hour period, the color of the slurry darkened to an orange and finally a dark orange/brown hue. The flask was removed from the oil bath and  
25 allowed to cool to room temperature. The slurry was then filtered, washed with toluene and partially dried under vacuum. In a dried 100 ml r.b. flask, 100 mg of a 20 wt % solution of (1,3-Me,BuCp)<sub>2</sub>ZrMe<sub>2</sub> in toluene was dissolved in 30 ml of toluene. The partially dried silica was transferred into the flask and the slurry was allowed to stand overnight at room temperature. The slurry was filtered through a frit and dried thoroughly  
30 under vacuum.

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**Polymerizations**

**[0148]** Polymerizations were performed for the catalyst systems prepared in Examples 17-23 utilizing the same procedure as described above for Examples 1-16.

**[0149]** Pertinent data, for the polymers prepared by the catalyst systems of  
5 Comparative Example 1 and Examples 17-23, is summarized in Table 2.



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TABLE 2. Polymerization Data Utilizing Catalyst Systems of Examples 1 and 17-23

Catalyst		Comonomer Incorporation	Average Mw	Average Mn	Average PDI	Yield	Activity (gP/gCat*hr)
Comp. 1	1	3.1	424377.6	254601	1.7	0.133	649.5
Comp. 1	2	3.2	430953.9	263320	1.6	0.123	656.0
Comp. 1	3	3	420634.5	272312	1.5	0.131	620.1
	average	3.1	425322	263411	2	0	642
	stddev	0.1	5224	8856	0	0	19
17	4	3.4	393658.9	224344	1.8	0.129	1249.7
17	5	3.5	402083	239361	1.7	0.137	1304.1
17	6	3.3	405971.2	238928	1.7	0.136	1286.1
	average	3.4	400571	234211	2	0	1280
	stddev	0.1	6294	8548	0	0	28
18	1	3.2	476505.8	283278	1.7	0.11	577.2
18	2	3.2	465474.7	282325	1.6	0.115	523.8
18	3	3.2	460351.6	276281	1.7	0.128	484.8
	average	3.2	467444	280628	2	0	529
	stddev	0.0	8255	3795	0	0	46
19	4	3	478902.2	267006	1.8	0.127	696.0
19	5	2.9	488375.1	301026	1.6	0.118	714.8
19	6	2.8	483302.6	294444	1.6	0.104	661.6
	average	2.9	483527	287492	2	0	691
	stddev	0.1	4740	18044	0	0	27
20	1	3.2	431988.3	263019	1.6	0.129	754.1
20	2	3.2	445204.4	257303	1.7	0.122	680.6
20	3	3.3	425137.3	262249	1.6	0.131	740.1
	average	3.2	434110	260857	2	0	725
	stddev	0.1	10200	3102	0	0	39
21	4	3.1	427548.3	246446	1.7	0.127	1020.2

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TABLE 2 (continued). Polymerization Data Utilizing Catalyst Systems of Examples 1 and 17-23

Catalyst		Comonomer Incorporation	Average Mw	Average Mn	Average PDI	Yield	Activity (gP/gCat*hr)
21	5	3.2	441603.3	274261	1.6	0.122	962.1
21	6	3.2	436116.1	261730	1.7	0.121	898.7
	average	3.2	435089	260812	2	0	960
	stddev	0.1	7084	13930	0	0	61
22	1	3.1	445283.3	256377	1.7	0.123	388.9
22	2	3.2	446511.3	258059	1.7	0.126	459.0
22	3	3.2	429995.3	255286	1.7	0.126	455.0
	average	3.2	440597	256574	2	0	434
	stddev	0.1	9202	1397	0	0	39
23	4	3.4	406183.4	227330	1.8	0.12	381.1
23	5					0.012	184.8
23	6	3.2	431091.8	222797	1.9	0.113	312.0
	average	3.3	418638	225063	2	0	293
	stddev	0.1	17613	3206	0	0	100

5

**EXAMPLE 24.**

**[0150]** In a 100 ml r.b. flask, 250 mg of triethylaluminum was dissolved in 30 ml of toluene. To this solution, 1.00 g. of silica (948 calcined at 200°C) was added. This slurry was allowed to stand overnight at room temperature. The slurry was filtered through a frit, washed with toluene (3 x 10 ml) and partially dried under vacuum. In a dried 100 ml r.b. flask, 100 mg of 5-fluoroindole was dissolved in 30 ml of *o*-xylene. The partially dried silica was transferred to the flask and slurried. An immediate, noticeable color change was observed from the off-white silica to a yellow-tinted slurry. The flask was placed in an oil bath at 140°C for three hours and stirred every half-hour. Over the three hour period, the color of the slurry darkened to an orange and finally a dark orange/brown hue. The flask was removed from the oil bath and allowed to cool to room temperature. The slurry was then filtered, washed with toluene and partially dried under vacuum. In a dried 100 ml r.b. flask, 100 mg of a 20 wt % solution (in toluene) of (1,3-Me<sub>2</sub>BuCp)<sub>2</sub>ZrMe<sub>2</sub> was dissolved in 30 ml of toluene. The partially dried silica was

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transferred into the flask and the slurry was allowed to stand overnight at room temperature. The slurry was filtered through a frit and dried thoroughly under vacuum.

**EXAMPLE 25.**

5 [0151] 0.25 grams of triethylaluminum in toluene were combined with 1.0 grams of silica (Davison 948 100°C vacuum dried) in a 100 flask. The resulting slurry was allowed to sit overnight. The resulting silica was filtered, and rinsed with several 10 ml portions of toluene. 0.1 grams of 4,5,6,7-tetrafluoroindole was added to silica, slurried in o-xylene and heated to 140°C for three hours. Over the three hour period, the color of the  
10 slurry darkened to an orange and finally a dark orange/brown hue. The silica was then filtered, rinsed with several 10 ml portions of toluene, and subsequently combined with 0.09 grams of a 20 wt % solution of (1,3-Me,BuCp)<sub>2</sub>ZrMe<sub>2</sub> in toluene. The supported catalyst was allowed to sit at room temperature for 1 hr. The catalyst was filtered, rinsed with several 10 ml portions of toluene, and dried under a vacuum.

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**EXAMPLE 26.**

[0152] 0.35 grams of triethylaluminum in toluene were combined with 1.0 grams of silica (Davison 948) in a 100 flask. The resulting slurry was allowed to sit overnight. The resulting silica was filtered, and rinsed with several 10 ml portions of toluene. 0.1  
20 grams of 5-fluoroindole was added to silica, slurried in o-xylene and heated to 140°C for three hours. Over the three hour period, the color of the slurry darkened to an orange and finally a dark orange/brown hue. The silica was then filtered, rinsed with several 10 ml portions of toluene, and subsequently combined with 0.09 grams of a 20 wt % solution of (1,3-Me,BuCp)<sub>2</sub>ZrMe<sub>2</sub> in toluene. The supported catalyst was allowed to sit at room  
25 temperature for 1 hr. The catalyst was filtered, rinsed with several 10 ml portions of toluene, and dried under a vacuum.

**EXAMPLE 27.**

[0153] 0.25 grams of triethylaluminum in toluene were combined with 1.0 grams  
30 of silica (Davison 948 100°C vacuum dried) in a 100 flask. The resulting slurry was allowed to sit overnight. The resulting silica was filtered, and rinsed with several 10 ml

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portions of toluene. 0.1 grams of indole was added to silica, slurried in o-xylene and heated to 140°C for three hours. Over the three hour period, the color of the slurry darkened to an orange and finally a dark orange/brown hue. The silica was then filtered, rinsed with several 10 ml portions of toluene, and subsequently combined with 0.09 grams of a 20 wt % solution of (1,3-Me,BuCp)<sub>2</sub>ZrMe<sub>2</sub> in toluene. The supported catalyst was allowed to sit at room temperature for 1 hr. The catalyst was filtered, rinsed with several 10 ml portions of toluene, and dried under a vacuum.

**EXAMPLE 28.**

10 **[0154]** 0.35 grams of triethylaluminum in toluene were combined with 1.0 grams of silica (Davison 948) in a 100 flask. The resulting slurry was heated to 140 C for three hours. The silica was filtered, and rinsed with several 10 ml portions of toluene. 0.1 grams of 5-fluoroindole was added to silica, slurried in o-xylene and heated to 140°C for three hours. Over the three hour period, the color of the slurry darkened to an orange and  
15 finally a dark orange/brown hue. The silica was then filtered, rinsed with several 10 ml portions of toluene, and subsequently combined with 0.09 grams of a 20 wt % solution of (1,3-Me,BuCp)<sub>2</sub>ZrMe<sub>2</sub> in toluene. The supported catalyst was allowed to sit at room temperature for 1 hr. The catalyst was filtered, rinsed with several 10 ml portions of toluene, and dried under a vacuum.

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**EXAMPLE 29.**

**[0155]** In a 100 ml r.b. flask, 250 mg of triethylaluminum was dissolved in 30 ml of toluene. To this solution, 1.00 g. of silica (948 calcined at 200C) was added. This slurry was allowed to stand overnight at room temperature. The slurry was filtered  
25 through a frit, washed with toluene (3 x 10 ml) and partially dried under vacuum. In a dried 100 ml r.b. flask, 200 mg of 5-fluoroindole was dissolved in 30 ml of o-xylene. The partially dried silica was transferred to the flask and slurried. An immediate, noticeable color change was observed from the off-white silica to a yellow-tinted slurry. The flask was placed in an oil bath at 140C for three hours and stirred every half-hour. Over the  
30 three hour period, the color of the slurry darkened to an orange and finally a dark orange/brown hue. The flask was remove from the oil bath and allowed to cool to room

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temperature. The slurry was then filtered, washed with toluene and partially dried under vacuum. In a dried 100 ml r.b. flask, 100 mg of a 20 wt % solution of (1,3-Me,BuCp)<sub>2</sub>ZrMe<sub>2</sub> in toluene was dissolved in 30 ml of toluene. The partially dried silica was transferred into the flask and the slurry was allowed to stand overnight at room  
5 temperature. The slurry was filtered through a frit and dried thoroughly under vacuum.

**EXAMPLE 30.**

10 **[0156]** 10.0 grams of triethylaluminum in toluene were combined with 40.0 grams of silica (Davison 948 200°C) in a 100 flask. The resulting slurry was allowed to sit overnight. The resulting silica was filtered, and rinsed with several 100 ml portions of toluene. 4.0 grams of 4,5,6,7-tetrafluoroindole was added to silica, slurried in o-xylene and heated to 140°C for three hours. Over the three hour period, the color of the slurry  
15 darkened to an orange and finally a dark orange/brown hue. The silica was then filtered, rinsed with several 100 ml portions of toluene, and dried under vacuum. 36.0 grams of the support was combined with 2.7 grams of a 20 wt % solution of (1,3-Me,BuCp)<sub>2</sub>ZrMe<sub>2</sub> in toluene. The supported catalyst was allowed to sit at room temperature for 1 hr. The catalyst was filtered, rinsed with several 100 ml portions of toluene, and dried under a  
20 vacuum.

**EXAMPLE 31.**

**[0157]** 10.0 grams of triethylaluminum in toluene were combined with 40.0 grams of silica (Davison 948 calcined @ 200 C) in a 100 flask. The resulting slurry sat  
25 overnight. The silica was filtered, and rinsed with several 100 ml portions of toluene. 4.0 grams of 5-fluoroindole was added to silica, slurried in o-xylene and heated to 140°C for three hours. Over the three hour period, the color of the slurry became yellow. The silica was then filtered, rinsed with several 100 ml portions of toluene, and dried under vacuum. 36.0 grams of this support was combined with 2.6 grams of a 20 wt % solution of (1,3-Me,BuCp)<sub>2</sub>ZrMe<sub>2</sub> in toluene. The supported catalyst was allowed to sit at room  
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temperature for 1 hr. The catalyst was filtered, rinsed with several 100 ml portions of toluene, and dried under a vacuum.

**EXAMPLE 32.**

5 [0158] In a 100 ml r.b. flask, 150 mg of indole was dissolved in 30 ml of *o*-xylene. 1.00 g of dried silica (146A) was transferred to the flask and slurried. No color change was observed. The flask was placed in an oil bath at 140°C for three hours and stirred every half-hour. No color change was observed over this period. The flask was removed from the oil bath and allowed to cool to room temperature. The slurry was then filtered, 10 washed with toluene and partially dried under vacuum. In a dried 100 ml r.b. flask, 100 mg of a 20 wt % solution (in toluene) of (1,3-Me,BuCp)<sub>2</sub>ZrMe<sub>2</sub> was dissolved in 30 ml of toluene. The partially dried silica was transferred into the flask and the slurry was allowed to stand overnight at room temperature. The slurry was filtered through a frit and dried thoroughly under vacuum.

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**EXAMPLE 33.**

[0159] In a 100 ml r.b. flask, 150 mg of 4,5,6,7-tetrafluoroindole was dissolved in 30 ml of *o*-xylene. 1.00 g of dried silica (146A) was transferred to the flask and slurried. An immediate, noticeable color change was observed from the off-white silica to a yellow-tinted slurry. The flask was placed in an oil bath at 100°C for three hours and stirred every 20 half-hour. Over the three hour period, the color of the slurry darkened slightly to a yellow-orange color. The flask was removed from the oil bath and allowed to cool to room temperature. The slurry was then filtered, washed with toluene and partially dried under vacuum. In a dried 100 ml r.b. flask, 100 mg of a 20 wt % solution (in toluene) of (1,3- 25 Me,BuCp)<sub>2</sub>ZrMe<sub>2</sub> was dissolved in 30 ml of toluene. The partially dried silica was transferred into the flask and the slurry was allowed to stand overnight at room temperature. The slurry was filtered through a frit and dried thoroughly under vacuum.

**EXAMPLE 34.**

30 [0160] In a 100 ml r.b. flask, 150 mg of 4,5,6,7-tetrafluoroindole was dissolved in 30 ml of *o*-xylene. 1.00 g of dried silica (146A) was transferred to the flask and slurried.

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An immediate, noticeable color change was observed from the off-white silica to a yellow-tinted slurry. The flask was placed in an oil bath at 120°C for three hours and stirred every half-hour. Over the three hour period, the color of the slurry darkened slightly to a orange-yellow color. The flask was remove from the oil bath and allowed to cool to room  
5 temperature. The slurry was then filtered, washed with toluene and partially dried under vacuum. In a dried 100 ml r.b. flask, 100 mg of a 20 wt % solution (in toluene) of (1,3-Me,BuCp)<sub>2</sub>ZrMe<sub>2</sub> was dissolved in 30 ml of toluene. The partially dried silica was transferred into the flask and the slurry was allowed to stand overnight at room temperature. The slurry was filtered through a frit and dried thoroughly under vacuum.

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**EXAMPLE 35.**

**[0161]** 0.25 grams of triethylaluminum in toluene were combined with 1.0 grams of silica (Davison 948 100°C vacuum dried) in a 100 flask. The resulting slurry was allowed to sit overnight. The resulting silica was filtered, and rinsed with several 10 ml  
15 portions of toluene. 0.1 grams of 5-fluoroindole was added to silica, slurried in o-xylene and heated to 140°C for three hours. Over the three hour period, the color of the slurry darkened to an orange and finally a dark orange/brown hue. The silica was then filtered, rinsed with several 10 ml portions of toluene, and subsequently combined with 0.09 grams of a 20 wt % solution of (1,3-Me,BuCp)<sub>2</sub>ZrMe<sub>2</sub> in toluene. The supported catalyst was  
20 allowed to sit at room temperature for 1 hr. The catalyst was filtered, rinsed with several 10 ml portions of toluene, and dried under a vacuum.

**EXAMPLE 36.**

**[0162]** In a 100 ml r.b. flask, 1.00 g of triethylaluminum was dissolved in 60 ml of  
25 toluene. To this solution, 5.00 g. of silica (948 calcined at 200°C) was added. This slurry was allowed to stand overnight at room temperature. The slurry was filtered through a frit, washed with toluene (3 x 10 ml), dried throughly under vacuum and labeled 146A. In a dried 100 ml r.b. flask, 150 mg of 4,5,6,7-tetrafluoroindole was dissolved in 30 ml of o-xylene. 1.00 g of dried silica (146A) was transferred to the flask and slurried. An  
30 immediate, noticeable color change was observed from the off-white silica to a yellow-tinted slurry. The flask was placed in an oil bath at 85°C for three hours and stirred every

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half-hour. Over the three hour period, the color of the slurry darkened very slightly. The flask was remove from the oil bath and allowed to cool to room temperature. The slurry was then filtered, washed with toluene and partially dried under vacuum. In a dried 100 ml r.b. flask, 100 mg of a 20 wt % solution (in toluene) of (1,3-Me,BuCp)<sub>2</sub>ZrMe<sub>2</sub> was dissolved in 30 ml of toluene. The partially dried silica was transferred into the flask and the slurry was allowed to stand overnight at room temperature.

**EXAMPLE 37.**

**[0163]** In a 100 ml r.b. flask, 150 mg of 4,5,6,7-tetrafluoroindole was dissolved in 30 ml of *o*-xylene. 1.00 g of dried silica (146A) was transferred to the flask and slurried. An immediate, noticeable color change was observed from the off-white silica to a yellow-tinted slurry. The flask was left at room temperature over three days. The color of the slurry stayed light in color. The slurry was then filtered, washed with toluene and partially dried under vacuum. In a dried 100 ml r.b. flask, 100 mg of a 20 wt % solution (in toluene) of (1,3-Me,BuCp)<sub>2</sub>ZrMe<sub>2</sub> was dissolved in 30 ml of toluene. The partially dried silica was transferred into the flask and the slurry was allowed to stand overnight at room temperature. The slurry was filtered through a frit and dried thoroughly under vacuum.

**Polymerizations**

**[0164]** Polymerizations were performed for the catalyst systems prepared in Examples 24-37 utilizing the same procedure as described above for Examples 1-16.

**[0165]** Pertinent data, for the polymers prepared by the catalyst systems of Comparative Example 1 and Examples 24-37, is summarized in Table 3.

**TABLE 3. Polymerization Data Utilizing Catalyst Systems of Examples 1 and 24-37**

Catalyst		Comonomer Incorporation	Average Mw	Average Mn	Average PDI	Yield	Activity (gP/gCat*hr)
Comp. 1	1	2.8	380220.2	219893	1.7	0.13	475.1
Comp. 1	2	2.8	376394.7	220195	1.7	0.13	608.4
Comp. 1	3	2.8	388153.5	225242	1.7	0.13	579.9
	average	2.8	381589	221777	2	0	554
	stddev	0.0	5998	3005	0	0	70
24	4	2.7	434129.6	254931	1.7	0.095	295.7
24	5	2.6	437231.6	246525	1.8	0.118	428.4



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24	6	2.9	432701	261855	1.7	0.124	606.4
	average	2.7	434687	254437	2	0	443
	stddev	0.2	2316	7677	0	0	156
25	1	3.1	358356.7	199537	1.8	0.141	1480.9
25	2	3.3	347803.9	195597	1.8	0.138	1274.5
25	3	3.2	353588.5	197912	1.8	0.139	1368.8
	average	3.2	353250	197682	2	0	1375
	stddev	0.1	5285	1980	0	0	103
26	4	2.9	410401.7	233119	1.8	0.113	589.4
26	5	2.9	425087.1	258169	1.6	0.129	748.5
26	6	2.9	404252.5	226393	1.8	0.128	707.2
	average	2.9	413247	239227	2	0	682
	stddev	0.0	10705	16746	0	0	83
27	1	3	419632.8	249435	1.7	0.11	432.1
27	2	2.8	442742	268179	1.7	0.058	344.9
27	3	2.9	446808.5	261866	1.7	0.124	336.5
	average	2.9	436394	259827	2	0	371
	stddev	0.1	14658	9537	0	0	53
28	4	3	390819.8	231964	1.7	0.123	855.2
28	5	3	409805	237484	1.7	0.132	931.7
28	6	2.8	343700	200670	1.7	0.12	1021.8
	average	2.9	381442	223373	2	0	936
	stddev	0.1	34036	19854	0	0	83
29	1	3	443182	253052	1.8	0.125	557.4
29	2	2.8	439174.3	252634	1.7	0.119	614.0
29	3	2.9	449515	266835	1.7	0.127	611.2
	average	2.9	443957	257507	2	0	594
	stddev	0.1	5214	8081	0	0	32
30	4	3.1	378248.8	225857	1.7	0.123	767.6
30	5	3.3	382525.6	224916	1.7	0.132	1066.7
30	6	3.2	376774.8	227907	1.7	0.128	998.9
	average	3.2	379183	226227	2	0	944
	stddev	0.1	2987	1529	0	0	157
31	4	2.9	402834.2	238283	1.7	0.121	826.2
31	5	2.8	418415.6	241266	1.7	0.125	815.3
31	6	2.9	404376	226705	1.8	0.12	794.7
	average	2.9	408542	235418	2	0	812
	stddev	0.1	8586	7691	0	0	16
32	1	2.6	492528.8	289158	1.7	0.063	140.0
32	2	2.8	541200.6	317437	1.7	0.065	144.4
32	3	2.7	537768	315793	1.7	0.067	148.9
	average	2.7	523832	307463	2	0	144

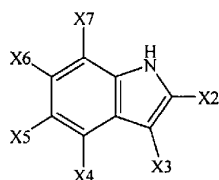
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	stddev	0.1	27164	15874	0	0	4
33	4	3.4	362652.7	207934	1.7	0.137	1461.1
33	5	3.3	360424.4	202956	1.8	0.137	1453.0
33	6	3.1	365856.1	211387	1.7	0.141	1710.9
	average	3.3	362978	207426	2	0	1542
	stddev	0.2	2730	4238	0	0	147
34	1	3.5	358544.4	207545	1.7	0.141	1446.3
34	2	3.4	347409.8	197193	1.8	0.14	1480.3
34	3	3.5	353951.7	200281	1.8	0.142	1457.9
	average	3.5	353302	201673	2	0	1462
	stddev	0.1	5596	5314	0	0	17
35	4	3.6	388779.6	211955	1.8	0.129	846.4
35	5	3.3	406451.5	254636	1.6	0.12	841.2
35	6	3	399957.7	225841	1.8	0.129	821.5
	average	3.3	398396	230811	2	0	836
	stddev	0.3	8939	21770	0	0	13
36	1	3.6	376244.7	221747	1.7	0.135	1014.6
36	2	3.4	373889.1	211149	1.8	0.133	989.0
36	3	3.3	376539.5	216765	1.7	0.133	916.1
	average	3.4	375558	216554	2	0	973
	stddev	0.2	1453	5302	0	0	51
37	4	3.2	362077.3	205626	1.8	0.13	964.1
37	5	3.2	370946.3	213202	1.7	0.133	1180.4
37	6	3.2	372298.1	216401	1.7	0.134	1202.5
	average	3.2	368441	211743	2	0	1116
	stddev	0.0	5552	5534	0	0	132

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## THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A catalyst system comprising a metallocene polymerization catalyst, and an activator wherein the activator comprises a heterocyclic compound
- 5 wherein the heterocyclic compound is selected from the group consisting of pyrroles, imidazoles, pyrazoles, pyrrolines, pyrroles, 3-pentafluorophenyl pyrrole, 4,5,6,7-tetrafluoroindole, 3,4-difluoropyrroles, and combinations thereof; in combination with an aluminium containing compound; wherein the aluminium containing compound is an alumoxane or an alkylaluminum
- 10 compound represented by the formula  $AlR_3$ , wherein each R is independently a substituted or unsubstituted alkyl group, and wherein the catalyst system further comprises a support material.
2. The catalyst system of claim 1, wherein the heterocyclic compound is
- 15 substituted with one or more substituent groups selected from the group consisting of a halogen atom, and a halogen atom containing group.
3. The catalyst system of claim 2, wherein the halogen atom or the halogen atom group comprises chlorine, fluorine or bromine.
- 20 4. The catalyst system of any one of claims 1 to 3, wherein the support material is treated with the alumoxane or the alkylaluminum compound such that the support has aluminium alkyl groups bonded thereto.
- 25 5. The catalyst system of claim 1, wherein the heterocyclic compound is an indole represented by:



wherein each of X2 to X7 is independently selected from the group consisting of hydrogen, halogen, an alkyl group, a halogenated or partially halogenated

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alkyl group, an aryl group, a halogenated or partially halogenated aryl group, an alkoxide group, a halogenated or partially halogenated alkoxide group, an aryloxy group, a halogenated or partially halogenated aryloxy group, an aryl substituted alkyl group, and a halogenated or partially halogenated aryl substituted alkyl group.

6. The catalyst system of claim 5, wherein the halogenated or partially halogenated group comprises a chlorine atom, a bromine atom or a fluorine atom.

7. The catalyst system of claim 1, wherein the activator is represented by one of the following formulae:

(a)  $R'_xM(JY)_y)_n$  or

(b)  $[(JY)_yR'_x)_n M-O-M((R'_x(JY)_y)_n)_m$  or

(c)  $(OMR'_x(JY)_y)_n$

wherein M is a Group 13 atom;

(JY) represents a substituted or unsubstituted heterocyclic group attached to M, wherein Y represents the heterocyclic group as a whole and J represents at least one heteroatom contained in group Y;

n is 1 or 2 in formula (a); n is 2 in formula (b); and n is a number from 1 to 1000 in formula (c);

m is a number from 1 to 10;

x + y = the valence of M in formula (a); x + y = the valence of M - 1 in formula (b); and x + y = valence of M - 2 in formula (c);

each R' is independently a substituted group bonded to M.

8. The catalyst system of claim 7, wherein J is bonded to M and wherein (JY) is not perhalogenated.

9. The catalyst system of claim 7, wherein M is Al or B; and

(JY) is a substituted or unsubstituted indolyl group where the substituents are selected from hydrogen, halogen, an alkyl group, a halogenated or partially

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halogenated alkyl group, an aryl group, a halogenated or partially halogenated aryl group, an aryl substituted alkyl group, a halogenated or partially halogenated aryl substituted alkyl group.

- 5 10. The catalyst system of claim 9, wherein R' is bonded to a support material.
11. The catalyst system of claim 10, wherein the support material is silica.
- 10 12. A polymerization process comprising contacting a catalyst system of any one of the preceding claims with an olefin.
13. The process of claim 12, wherein the process is a gas phase or slurry phase process.
- 15 14. A polymer produced utilizing the catalyst system of any of the claims 1 to 11.
- 20 15. The polymer of claim 14, wherein the polymer is an ethylene based polymer.
- 25 16. The catalyst system of any of the claims 1 to 11, wherein the catalyst system is prepared by combining a heterocyclic compound with an aluminoxane or an alkylaluminum compound and a support material such that the support material contains aluminium alkyl groups bonded thereto.
17. A catalyst system according to claim 1 substantially as hereinbefore described with reference to the examples.