

Claims:

We claim:

1. A method for preparing supported alumoxane comprising contacting at least one support material, at least one hydrocarbyl aluminum compound and at least one non-hydrolytic oxygen-containing compound in an aliphatic solvent.
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2. The method of claim 1, wherein the support material is silica, alumina, alumina-silica or a derivative thereof.
- 10 3. The method of claim 1 or 2, wherein the support material has an average particle size between 1 and 200 microns, an average pore volume of between 0.05 and 5 mL/g, and a surface area between 50 and 800 m²/g.
4. The method of claims 1-3, wherein the support material has been treated with one or
15 more of a Bronsted acid, a Lewis acid, a salt and a Lewis base.
5. The method of claims 1-4, wherein the support material comprises a silylating agent.
6. The method of claims 1-5, wherein the support material comprises a hydrocarbyl
20 aluminum compound.
7. The method of claims 1-6, wherein one or more of the support material, the hydrocarbyl aluminum compound and the alumoxane precursor comprises an electron withdrawing anion.
- 25 8. The method of claims 1-7, wherein the hydrocarbyl aluminum compound is R₃Al wherein each R, which may be the same or different, is independently a hydrocarbon containing between 1 and 30 carbon atoms.
9. The method of claims 1-8, wherein the hydrocarbyl aluminum compound is selected
30 from a combination of trimethyl aluminum and trioctylaluminum, and a combination of trimethyl aluminum and triisobutyl aluminum.

10. The method of claims 1-9, wherein the hydrocarbyl aluminum compound comprises trimethyl aluminum.
11. The method of claims 1-10, wherein the hydrocarbyl aluminum compound includes a
5 mixture comprising an alumoxane.
12. The method of claims 1-11, wherein the non-hydrolytic oxygen-containing compound is one or more of carbon dioxide, a carboxylic acid, an ester, an anhydride, an alcohol or combination thereof.
- 10 13. The method of claims 1-11, wherein the non-hydrolytic oxygen-containing compound is one or more of carbon dioxide, a carboxylic acid, an ester, an anhydride and an alcohol or combination thereof, optionally containing water.
- 15 14. The method of claims 1-13, wherein the non-hydrolytic oxygen-containing compound is $R^1R^2C=CR^3CO_2H$ wherein each of R^1 and R^2 is independently hydrogen, alkyl, alkenyl, aryl or heteroatom containing group and R^3 is alkyl, alkenyl, aryl or heteroatom containing group.
- 20 15. The method of claims 1-14, wherein the non-hydrolytic oxygen-containing compound is methacrylic acid.
16. The method of claims 1-15, wherein the hydrocarbyl aluminum compound includes the non-hydrolytic oxygen-containing compound.
- 25 17. The method of claims 1-15, wherein the hydrocarbyl aluminum compound is one or more of trimethylaluminum, triethylaluminum, tripropylaluminum, tri-n-butylaluminum, tri-isobutyl-aluminum, tri(2-methylpentyl)aluminum, trihexylaluminum, tri-n-octylaluminum, tri-n-decylaluminum, dimethyl aluminum methoxide, dimethyl aluminum ethoxide, dimethyl aluminum isopropoxide, dimethyl aluminum n-butoxide, dimethyl aluminum isobutoxide,
30 diethyl aluminum methoxide, diethyl aluminum ethoxide, diethyl aluminum isopropoxide, diethyl aluminum n-butoxide, diethyl aluminum isobutoxide, diisobutyl aluminum methoxide, diisobutyl aluminum ethoxide, diisobutyl aluminum isopropoxide, diisobutyl aluminum n-butoxide, diisobutyl aluminum isobutoxide, di-n-hexyl aluminum methoxide, di-n-hexyl

aluminum ethoxide, di-n-hexyl aluminum isopropoxide, di-n-hexyl aluminum n-butoxide, di-n-hexyl aluminum isobutoxide, methyl aluminum dimethoxide, methyl aluminum diethoxide, methyl aluminum diisopropoxide, methyl aluminum di-n-butoxide, methyl aluminum diisobutoxide, ethyl aluminum dimethoxide, ethyl aluminum diethoxide, ethyl aluminum diisopropoxide, ethyl aluminum di-n-butoxide, ethyl aluminum diisobutoxide, isobutyl aluminum dimethoxide, isobutyl aluminum diethoxide, isobutyl aluminum diisopropoxide, isobutyl aluminum di-n-butoxide, isobutyl aluminum diisobutoxide, n-hexylaluminum dimethoxide, n-hexyl aluminum diethoxide, n-hexyl aluminum diisopropoxide, n-hexyl aluminum di-n-butoxide, n-hexyl aluminum diisobutoxide, aluminum trimethoxide, aluminum triethoxide, aluminum triisopropoxide, aluminum tri-n-butoxide, tetramethyldialuminumdiisopropoxide, tetramethyldialuminumdi-tert-butoxide, tetramethyldialuminumditert-butoxide, pentamethyldialuminumtert-butoxide and aluminum triisobutoxide.

18. The method of any of claims 1-17, wherein the hydrocarbyl aluminum compound is one or more of trimethylaluminum, triethylaluminum and dimethyl aluminum isobutoxide.

19. The method of claims 1-15, wherein at least one hydrocarbyl aluminum and at least one non-hydrolytic oxygen-containing compound are combined and then added to at least one support material.

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20. The method of claims 1-15, wherein at least one hydrocarbyl aluminum compound and at least one non-hydrolytic oxygen-containing compound are combined under conditions of -80 to 200 °C prior to contact with the support material.

21. The method of claims 1-15, wherein at least one support material, at least one hydrocarbyl aluminum compound and at least one non-hydrolytic oxygen-containing compound are combined under conditions of 60°C to 200°C.

22. A method for preparing a catalyst system comprising contacting the supported alumoxane of any of claims 1-21 with a catalyst compound having a group 3 through group 12 metal atom or lanthanide atom.

23. The method of claim 22, wherein the supported alumoxane is heated to a temperature of from 60°C to 200°C prior to contact with the catalyst compound.

24. The method of claims 22 or 23, wherein the catalyst compound is an unbridged
 5 metallocene catalyst compound represented by the formula: $\text{Cp}^{\text{A}}\text{Cp}^{\text{B}}\text{M}'\text{X}'_{\text{n}}$, wherein each of Cp^{A} and Cp^{B} is independently selected from the group consisting of cyclopentadienyl ligands and ligands isolobal to cyclopentadienyl, one or both of Cp^{A} and Cp^{B} may contain heteroatoms, and one or both of Cp^{A} and Cp^{B} may be substituted by one or more R'' groups, wherein M' is an element selected from the group consisting of Groups 3 through 12 and lanthanide Group,
 10 wherein X' is an anionic ligand, wherein n is 0 or an integer from 1 to 4, wherein R'' is selected from the group consisting of alkyl, lower alkyl, substituted alkyl, heteroalkyl, alkenyl, lower alkenyl, substituted alkenyl, heteroalkenyl, alkynyl, lower alkynyl, substituted alkynyl, heteroalkynyl, alkoxy, lower alkoxy, aryloxy, alkylthio, lower alkylthio, arylthio, aryl, substituted aryl, heteroaryl, aralkyl, aralkylene, alkaryl, alkarylene, haloalkyl, haloalkenyl,
 15 haloalkynyl, heteroalkyl, heterocycle, heteroaryl, a heteroatom-containing group, hydrocarbyl, lower hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl, silyl, boryl, phosphino, phosphine, amino, amine, ether, and thioether.

25. The method of any of claims 22-24, wherein the metallocene catalyst compound is a
 20 bridged metallocene catalyst compound represented by the formula: $\text{Cp}^{\text{A}}(\text{A})\text{Cp}^{\text{B}}\text{M}'\text{X}'_{\text{n}}$, wherein each of Cp^{A} and Cp^{B} is independently selected from the group consisting of cyclopentadienyl ligands and ligands isolobal to cyclopentadienyl, one or both of Cp^{A} and Cp^{B} may contain heteroatoms, and one or both of Cp^{A} and Cp^{B} may be substituted by one or more R'' groups, wherein M' is an element selected from the group consisting of Groups 3 through
 25 12 and lanthanide Group, wherein X' is an anionic ligand, wherein n is 0 or an integer from 1 to 4, wherein (A) is selected from the group consisting of divalent alkyl, divalent lower alkyl, divalent substituted alkyl, divalent heteroalkyl, divalent alkenyl, divalent lower alkenyl, divalent substituted alkenyl, divalent heteroalkenyl, divalent alkynyl, divalent lower alkynyl, divalent substituted alkynyl, divalent heteroalkynyl, divalent alkoxy, divalent lower alkoxy,
 30 divalent aryloxy, divalent alkylthio, divalent lower alkylthio, divalent arylthio, divalent aryl, divalent substituted aryl, divalent heteroaryl, divalent aralkyl, divalent aralkylene, divalent alkaryl, divalent alkarylene, divalent haloalkyl, divalent haloalkenyl, divalent haloalkynyl, divalent heteroalkyl, divalent heterocycle, divalent heteroaryl, a divalent heteroatom-

containing group, divalent hydrocarbyl, divalent lower hydrocarbyl, divalent substituted hydrocarbyl, divalent heterohydrocarbyl, divalent silyl, divalent boryl, divalent phosphino, divalent phosphine, divalent amino, divalent amine, divalent ether, divalent thioether; wherein R'' is selected from the group consisting of alkyl, lower alkyl, substituted alkyl, heteroalkyl, alkenyl, lower alkenyl, substituted alkenyl, heteroalkenyl, alkynyl, lower alkynyl, substituted alkynyl, heteroalkynyl, alkoxy, lower alkoxy, aryloxy, alkylthio, lower alkylthio, arylthio, aryl, substituted aryl, heteroaryl, aralkyl, aralkylene, alkaryl, alkarylene, haloalkyl, haloalkenyl, haloalkynyl, heteroalkyl, heterocycle, heteroaryl, a heteroatom-containing group, hydrocarbyl, lower hydrocarbyl, substituted hydrocarbyl, heterohydrocarbyl, silyl, boryl, phosphino, phosphine, amino, amine, ether, and thioether.

26. The method of any of claims 22-25, wherein the catalyst compound is a metallocene catalyst compound represented by the formula:



wherein Cp is independently a cyclopentadienyl ligand or ligand structurally similar to cyclopentadienyl, M is a group 4 transition metal, G is a heteroatom group represented by the formula JR^*_z where J is N, P, O or S, and R* is a linear, branched, or cyclic C₁-C₂₀ hydrocarbyl and z is 1 or 2, T is a bridging group, and y is 0 or 1, X is an anionic ligand, and m=1, n= 1, 2 or 3, q=0, 1, 2 or 3, and the sum of m+n+q is equal to the oxidation state of the transition metal.

27. The method of any of claims 22-26, wherein the catalyst compound is a metallocene catalyst compound selected from the group consisting of:

bis(1-methyl, 3-n-butyl cyclopentadienyl) zirconium dichloride;

bis(1-methyl, 3-n-butyl cyclopentadienyl) zirconium dimethyl;

dimethylsilyl bis(tetrahydroindenyl) zirconium dichloride;

dimethylsilyl bis(tetrahydroindenyl) zirconium dimethyl;

bis(n-propylcyclopentadienyl) hafnium dichloride;

bis(n-propylcyclopentadienyl) hafnium dimethyl;

dimethylsilyl (tetramethylcyclopentadienyl)(cyclododecylamido)titanium dimethyl;

dimethylsilyl (tetramethylcyclopentadienyl)(cyclododecylamido)titanium dichloride;

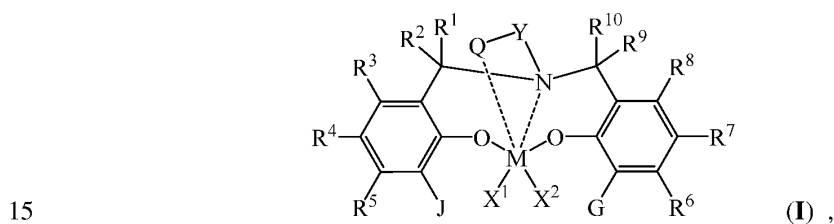
dimethylsilyl (tetramethylcyclopentadienyl)(t-butylamido)titanium dimethyl;

dimethylsilyl (tetramethylcyclopentadienyl)(t-butylamido)titanium dichloride;

μ -(CH₃)₂Si(cyclopentadienyl)(1-adamantylamido)M(R)₂;

- μ -(CH₃)₂Si(3-tertbutylcyclopentadienyl)(1-adamantylamido)M(R)₂;
 μ -(CH₃)₂(tetramethylcyclopentadienyl)(1-adamantylamido)M(R)₂;
 μ -(CH₃)₂Si(tetramethylcyclopentadienyl)(1-adamantylamido)M(R)₂;
 μ -(CH₃)₂C(tetramethylcyclopentadienyl)(1-adamantylamido)M(R)₂;
 5 μ -(CH₃)₂Si(tetramethylcyclopentadienyl)(1-tertbutylamido)M(R)₂;
 μ -(CH₃)₂Si(fluorenyl)(1-tertbutylamido)M(R)₂;
 μ -(CH₃)₂Si(tetramethylcyclopentadienyl)(1-cyclododecylamido)M(R)₂;
 μ -(C₆H₅)₂C(tetramethylcyclopentadienyl)(1-cyclododecylamido)M(R)₂; and
 μ -(CH₃)₂Si(η^5 -2,6,6-trimethyl-1,5,6,7-tetrahydro-*s*-indacen-1-yl)(tertbutylamido)M(R)₂;
 10 where M is selected from a group consisting of Ti, Zr, and Hf; and R is selected from halogen
 or C₁ to C₅ alkyl, or mixtures thereof.

28. The method of claim 22, wherein the catalyst compound is a bis(phenolate) catalyst compound represented by Formula (I):

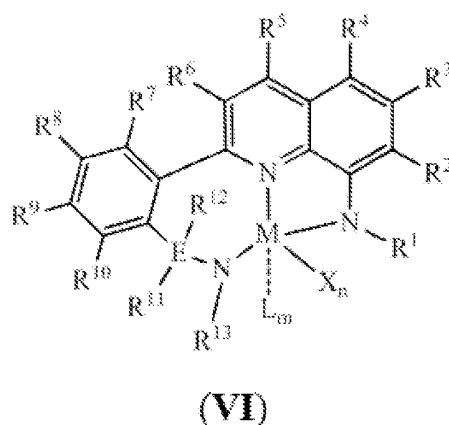
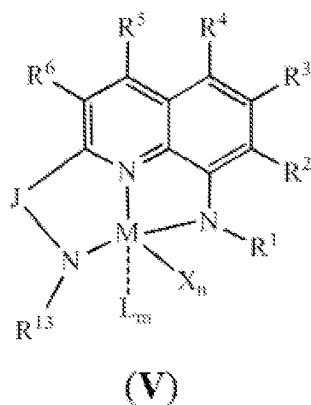


- wherein M is a Group 4 metal, X¹ and X² are independently a univalent C₁-C₂₀ hydrocarbyl, C₁-C₂₀ substituted hydrocarbyl, a heteroatom or a heteroatom-containing group, or X¹ and X² join together to form a C₄-C₆₂ cyclic or polycyclic ring structure. R¹, R², R³, R⁴, R⁵, R⁶, R⁷, R⁸, R⁹, and R¹⁰ is independently hydrogen, C₁-C₄₀ hydrocarbyl, C₁-C₄₀ substituted hydrocarbyl, a
 20 heteroatom or a heteroatom-containing group, or two or more of R¹, R², R³, R⁴, R⁵, R⁶, R⁷, R⁸, R⁹, or R¹⁰ are joined together to form a C₄-C₆₂ cyclic or polycyclic ring structure, or a combination thereof. Q is a neutral donor group. J is heterocycle, a substituted or unsubstituted C₇-C₆₀ fused polycyclic group, where at least one ring is aromatic and where at least one ring, which may or may not be aromatic, has at least five ring atoms. G is as defined for J or may be
 25 hydrogen, C₂-C₆₀ hydrocarbyl, C₁-C₆₀ substituted hydrocarbyl, or may independently form a C₄-C₆₀ cyclic or polycyclic ring structure with R⁶, R⁷, or R⁸ or a combination thereof. Y is divalent C₁-C₂₀ hydrocarbyl or divalent C₁-C₂₀ substituted hydrocarbyl or (-Q*-Y-) together form a heterocycle.

- wherein R³, R⁴, R⁵, R⁷, R⁸, R⁹, R¹⁰, R¹⁵, R¹⁶, and R¹⁷ are optionally substituted by halogen, -NR¹¹₂, -OR¹¹ or -SiR¹²₃;
- wherein R³ optionally bonds with R⁴, R⁴ optionally bonds with R⁵, R⁷ optionally bonds with R¹⁰, R¹⁰ optionally bonds with R⁹, R⁹ optionally bonds with R⁸, R¹⁷ optionally bonds with R¹⁶,
 5 and R¹⁶ optionally bonds with R¹⁵, in each case to independently form a five-, six- or seven-membered carbocyclic or heterocyclic ring, the heterocyclic ring comprising at least one atom from the group consisting of N, P, O and S;
- R¹³ is C₁-C₂₀-alkyl bonded with the aryl ring via a primary or secondary carbon atom,
 R¹⁴ is chlorine, bromine, iodine, -CF₃ or -OR¹¹, or C₁-C₂₀-alkyl bonded with the aryl ring;
- 10 each R¹¹ is independently hydrogen, C₁-C₂₂-alkyl, C₂-C₂₂-alkenyl, C₆-C₂₂-aryl, arylalkyl where alkyl has from 1 to 10 carbon atoms and aryl has from 6 to 20 carbon atoms, or -SiR¹²₃, wherein R¹¹ is optionally substituted by halogen, or two R¹¹ radicals optionally bond to form a five- or six-membered ring;
- each R¹² is independently hydrogen, C₁-C₂₂-alkyl, C₂-C₂₂-alkenyl, C₆-C₂₂-aryl, arylalkyl where
 15 alkyl has from 1 to 10 carbon atoms and aryl has from 6 to 20 carbon atoms, or two R¹² radicals optionally bond to form a five- or six-membered ring,
- each of E¹, E², and E³ is independently carbon, nitrogen or phosphorus;
- each u is independently 0 if E¹, E², and E³ is nitrogen or phosphorus and is 1 if E¹, E², and E³ is carbon,
- 20 each X is independently fluorine, chlorine, bromine, iodine, hydrogen, C₁-C₂₀-alkyl, C₂-C₁₀-alkenyl, C₆-C₂₀-aryl, arylalkyl where alkyl has from 1 to 10 carbon atoms and aryl has from 6 to 20 carbon atoms, -NR¹⁸₂, -OR¹⁸, -SR¹⁸, -SO₃R¹⁸, -OC(O)R¹⁸, -CN, -SCN, β-diketonate, -CO, -BF₄⁻, -PF₆⁻ or bulky non-coordinating anions, and the radicals X can be bonded with one another;
- 25 each R¹⁸ is independently hydrogen, C₁-C₂₀-alkyl, C₂-C₂₀-alkenyl, C₆-C₂₀-aryl, arylalkyl where alkyl has from 1 to 10 carbon atoms and aryl has from 6 to 20 carbon atoms, or -SiR¹⁹₃, wherein R¹⁸ can be substituted by halogen or nitrogen- or oxygen-containing groups and two R¹⁸ radicals optionally bond to form a five- or six-membered ring;
- each R¹⁹ is independently hydrogen, C₁-C₂₀-alkyl, C₂-C₂₀-alkenyl, C₆-C₂₀-aryl or arylalkyl
 30 where alkyl has from 1 to 10 carbon atoms and aryl has from 6 to 20 carbon atoms, wherein R¹⁹ can be substituted by halogen or nitrogen- or oxygen-containing groups or two R¹⁹ radicals optionally bond to form a five- or six-membered ring;
- s is 1, 2, or 3,

D is a neutral donor, and
t is 0 to 2.

31. The method of claim 22, wherein the catalyst compound comprises , the catalyst is a
5 quinolinyldiamido transition metal complex represented by formulas (V) and (VI):

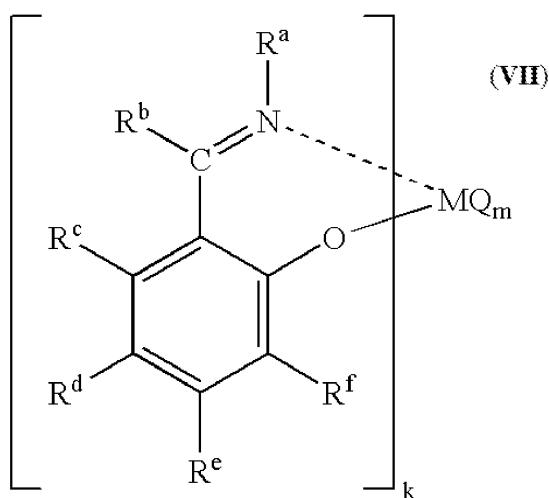


wherein:

- M is a Group 3-12 metal;
- J is a three-atom-length bridge between the quinoline and the amido nitrogen;
- 10 E is selected from carbon, silicon, or germanium;
- X is an anionic leaving group;
- L is a neutral Lewis base;
- R¹ and R¹³ are independently selected from the group consisting of hydrocarbyls, substituted hydrocarbyls, and silyl groups;
- 15 R² through R¹² are independently selected from the group consisting of hydrogen, hydrocarbyls, alkoxy, silyl, amino, aryloxy, substituted hydrocarbyls, halogen, and phosphino;
- n is 1 or 2;
- m is 0, 1, or 2
- n+m is not greater than 4; and
- 20 any two adjacent R groups (e.g. R¹ & R², R² & R³, etc.) may be joined to form a substituted or unsubstituted hydrocarbyl or heterocyclic ring, where the ring has 5, 6, 7, or 8 ring atoms and where substitutions on the ring can join to form additional rings;
- any two X groups may be joined together to form a dianionic group;
- any two L groups may be joined together to form a bidentate Lewis base;

an X group may be joined to an L group to form a monoanionic bidentate group.

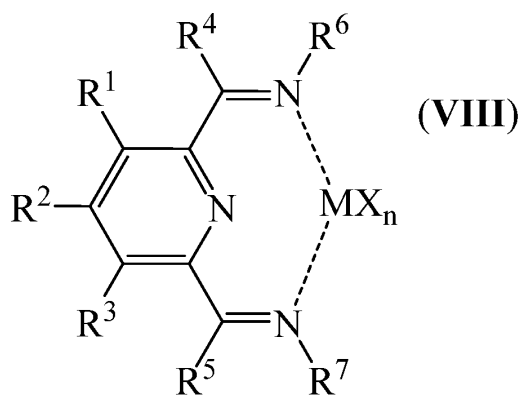
32. The method of claim 22, wherein the catalyst compound comprises a phenoxyimine compound represented by the formula (VII):



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 wherein M represents a transition metal atom selected from the groups 3 to 11 metals in the periodic table; k is an integer of 1 to 6; m is an integer of 1 to 6; R^a to R^f may be the same or different from one another and each represent a hydrogen atom, a halogen atom, a hydrocarbon group, a heterocyclic compound residue, an oxygen-containing group, a nitrogen-containing group, a boron-containing group, a sulfur-containing group, a phosphorus-containing group, a silicon-containing group, a germanium-containing group or a tin-containing group, among
 10 which 2 or more groups may be bound to each other to form a ring; when k is 2 or more, R^a groups, R^b groups, R^c groups, R^d groups, R^e groups, or R^f groups may be the same or different from one another, one group of R^a to R^f contained in one ligand and one group of R^a to R^f
 15 contained in another ligand may form a linking group or a single bond, and a heteroatom contained in R^a to R^f may coordinate with or bind to M; m is a number satisfying the valence of M; Q represents a hydrogen atom, a halogen atom, an oxygen atom, a hydrocarbon group, an oxygen-containing group, a sulfur-containing group, a nitrogen-containing group, a boron-containing group, an aluminum-containing group, a phosphorus-containing group, a halogen-containing group, a heterocyclic compound residue, a silicon-containing group, a germanium-containing group or a tin-containing group; when m is 2 or more, a plurality of groups
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represented by Q may be the same or different from one another, and a plurality of groups represented by Q may be mutually bound to form a ring.

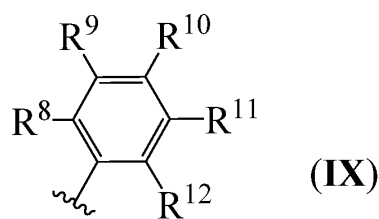
33. The method of claim 22, wherein the catalyst compound comprises a bis(imino)pyridyl
5 of the formula (VIII):



wherein :

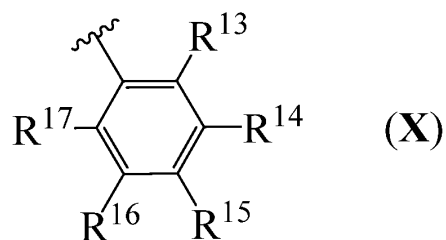
M is Co or Fe; each X is an anion; n is 1, 2 or 3, so that the total number of negative charges on said anion or anions is equal to the oxidation state of a Fe or Co atom present in (II);

- 10 R¹, R² and R³ are each independently hydrogen, hydrocarbyl, substituted hydrocarbyl, or an inert functional group;
R⁴ and R⁵ are each independently hydrogen, hydrocarbyl, an inert functional group or substituted hydrocarbyl;



R⁶ is formula IX;

- 15 and R⁷ is formula X;



R^8 and R^{13} are each independently hydrocarbyl, substituted hydrocarbyl or an inert functional group;

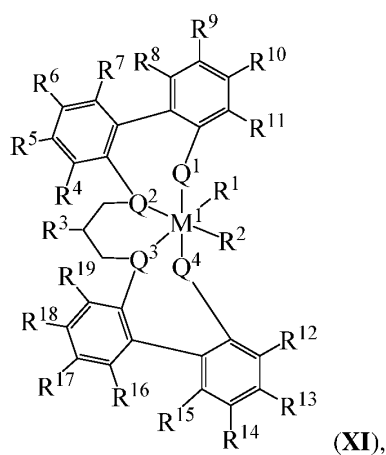
R^9 , R^{10} , R^{11} , R^{14} , R^{15} and R^{16} are each independently hydrogen, hydrocarbyl, substituted hydrocarbyl or an inert functional group;

R^{12} and R^{17} are each independently hydrogen, hydrocarbyl, substituted hydrocarbyl or an inert functional group;

and provided that any two of R^8 , R^9 , R^{10} , R^{11} , R^{12} , R^{13} , R^{14} , R^{15} , R^{16} and R^{17} that are adjacent to one another, together may form a ring.

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34. The method of claim 22, wherein the catalyst compound is represented by the formula (XI):



M^1 is selected from the group consisting of titanium, zirconium, hafnium, vanadium, niobium, tantalum, chromium, molybdenum and tungsten;

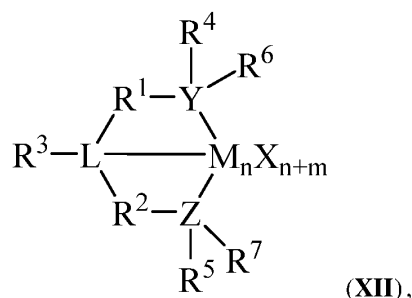
each of Q^1 , Q^2 , Q^3 , and Q^4 is independently oxygen or sulfur;

at least one of Q^1 , Q^2 , Q^3 , and Q^4 is oxygen, alternately all of Q^1 , Q^2 , Q^3 , and Q^4 are oxygen.

R^1 – R^{19} are independently hydrogen, halogen, hydroxyl, hydrocarbyl, or substituted hydrocarbyl (such as C_1 – C_{10} alkyl, C_1 – C_{10} alkoxy, C_6 – C_{20} aryl, C_6 – C_{10} aryloxy, C_2 – C_{10} alkenyl,

C₂-C₄₀ alkenyl, C₇-C₄₀ arylalkyl, C₇-C₄₀ alkylaryl, C₈-C₄₀ arylalkenyl, or conjugated diene which is optionally substituted with one or more hydrocarbyl, tri(hydrocarbyl) silyl or tri(hydrocarbyl) silylhydrocarbyl, the diene having up to 30 atoms other than hydrogen.

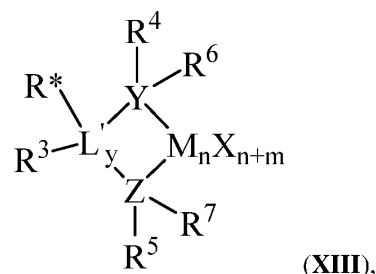
- 5 35. A method according to claim 22, wherein the catalyst is represented by Formula (XII):



- wherein M is a Group 3 to 12 transition metal or a Group 13 or 14 main group metal; each X is independently an anionic leaving group; y is 0 or 1; n is the oxidation state of M; m is the formal charge of the ligand represented by YZL or YZL'; L is a Group 15 or 16 element; L' is a group 15 or 16 element or Group 14 containing group; Y is a Group 15 element; Z is a Group 15 element; R¹ and R² are independently a C₁ to C₂₀ hydrocarbon group, a heteroatom containing group having up to twenty carbon atoms, silicon, germanium, tin, lead, or phosphorus; R¹ and R² may be interconnected to each other; R³ is absent, a hydrocarbon group, hydrogen, a halogen, or a heteroatom containing group; R⁴ and R⁵ are independently an alkyl group, an aryl group, a substituted aryl group, a cyclic alkyl group, a substituted cyclic alkyl group, a cyclic aralkyl group, a substituted cyclic aralkyl group, or a multiple ring system; R⁴ and R⁵ may be interconnected to each other; R⁶ and R⁷ are independently absent, hydrogen, an alkyl group, a halogen, a heteroatom, or a hydrocarbyl group; and R* is absent, hydrogen, a Group 14 atom containing group, a halogen, or a heteroatom containing group.

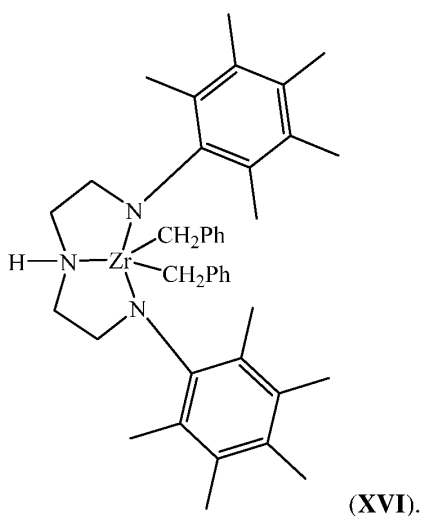
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36. A method according to claim 22, wherein the catalyst is represented by Formula (XIII):



wherein M is a Group 3 to 12 transition metal or a Group 13 or 14 main group metal; each X is independently an anionic leaving group; y is 0 or 1; n is the oxidation state of M; m is the formal charge of the ligand represented by YZL or YZL'; L is a Group 15 or 16 element; L' is a group 15 or 16 element or Group 14 containing group; Y is a Group 15 element; Z is a Group 15 element; R¹ and R² are independently a C₁ to C₂₀ hydrocarbon group, a heteroatom containing group having up to twenty carbon atoms, silicon, germanium, tin, lead, or phosphorus; R¹ and R² may be interconnected to each other; R³ is absent, a hydrocarbon group, hydrogen, a halogen, or a heteroatom containing group; R⁴ and R⁵ are independently an alkyl group, an aryl group, a substituted aryl group, a cyclic alkyl group, a substituted cyclic alkyl group, a cyclic aralkyl group, a substituted cyclic aralkyl group, or a multiple ring system; R⁴ and R⁵ may be interconnected to each other; R⁶ and R⁷ are independently absent, hydrogen, an alkyl group, a halogen, a heteroatom, or a hydrocarbyl group; and R* is absent, hydrogen, a Group 14 atom containing group, a halogen, or a heteroatom containing group.

37. A method according to claim 22, wherein the catalyst comprises a catalyst of Formula (XVI):



38. A method of polymerizing olefins to produce a polyolefin composition comprising contacting at least one olefin with the catalyst system of any of claims 22-37 and obtaining a polyolefin having no detectable aromatic hydrocarbon.

39. A method of polymerizing olefins in a gas-phase process to produce a polyolefin composition comprising contacting at least one olefin with the catalyst system of any of claims 22-37 and obtaining a polyolefin having no detectable aromatic hydrocarbon.
- 5 40. A method of polymerizing olefins to produce a polyolefin composition comprising contacting at least one olefin with the catalyst system of any of claims 22-37 and obtaining a polyolefin having 0 ppm of aromatic hydrocarbon.
- 10 41. A method of polymerizing olefins to produce a polyolefin composition comprising contacting at least one olefin with the catalyst system of any of claims 22-37 and obtaining a polyolefin having 0 ppm of toluene.