

BIS(AMINOPHENYLPHENOL) LIGANDS AND TRANSITION METAL COMPOUNDS PREPARED THEREFROM

FIELD

[0001] The present disclosure is directed to bis(aminophenylphenol) ligands and transition metal compounds prepared therefrom. The disclosure is also directed to methods of preparing the ligands and transition metal compounds.

BACKGROUND

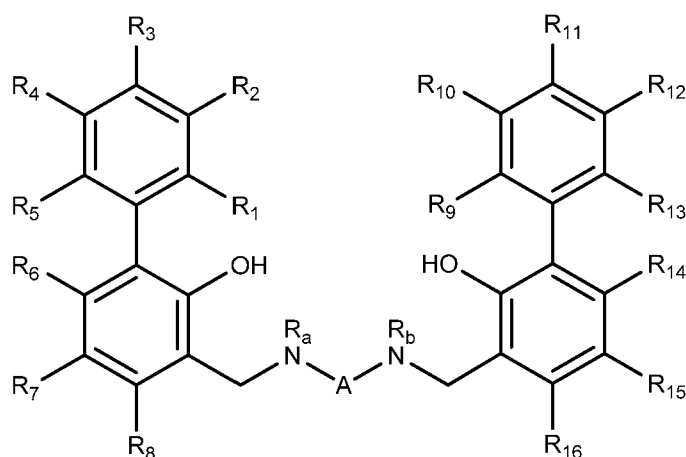
[0002] A major focus of the polyolefin industry in recent years has been on the development of new catalysts that deliver new and improved products. Bulky ligand transition metal compounds, for example, are now widely utilized in catalyst compositions to produce polyolefin polymers, such as polyethylene polymers.

[0003] It is recognized in the art that small differences in the molecular structure of a catalyst compound can greatly impact catalyst performance and that this is often governed by ligand structure. Therefore considerable effort has been expended in designing new ligand structures that may lead to catalysts having enhanced or differentiated performance.

[0004] It would therefore be desirable to provide new ligands and methods for their synthesis. It would also be desirable to provide new transition metal compounds based on the new ligands.

SUMMARY

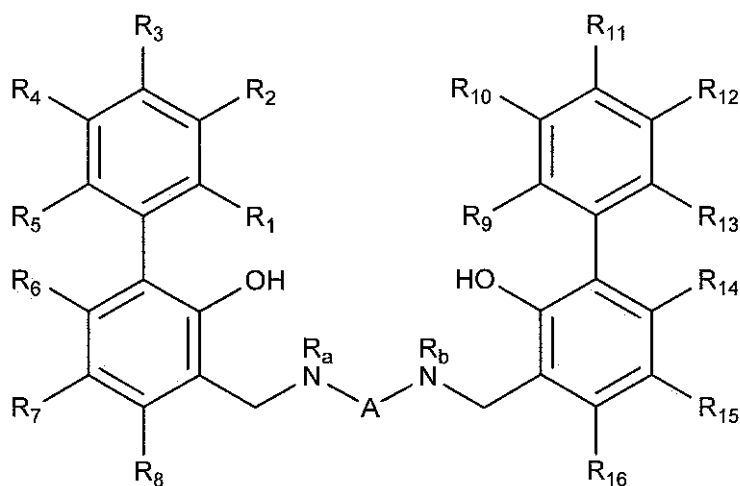
[0005] There is provided a bis(aminophenylphenol) ligand of formula (I):



(I)

wherein each of R_1 , R_2 , R_3 , R_4 , R_5 , R_6 , R_7 , R_8 , R_9 , R_{10} , R_{11} , R_{12} , R_{13} , R_{14} , R_{15} and R_{16} is independently selected from the group consisting of hydride, halide, optionally substituted hydrocarbyl, heteroatom-containing optionally substituted hydrocarbyl, alkoxy, aryloxy, silyl, boryl, dialkyl amino, alkylthio, arylthio and seleno, with the proviso that none of R_1 , R_2 , R_3 , R_4 , R_5 , R_9 , R_{10} , R_{11} , R_{12} and R_{13} comprise fluorine; optionally two or more R groups can combine together into ring structures with such ring structures having from 3 to 100 non-hydrogen atoms in the ring; A is a bridging group having from one to 50 non-hydrogen atoms; R_a and R_b are independently selected from hydride or optionally substituted hydrocarbyl, or, optionally, R_a and R_b may be joined to form a bridging group, E, having from one to 50 non-hydrogen atoms; and when R_a and R_b are not joined to form a bridging group, A is not $-(CH_2-CH_2)-$.

[0005a] In one aspect, there is provided a bis(aminophenylphenol) ligand of formula (I):



(I)

wherein each of R_1 , R_2 , R_3 , R_4 , R_5 , R_6 , R_7 , R_8 , R_9 , R_{10} , R_{11} , R_{12} , R_{13} , R_{14} , R_{15} and R_{16} is independently selected from the group consisting of hydride, halide, optionally substituted hydrocarbyl, heteroatom-containing optionally substituted hydrocarbyl, alkoxy, aryloxy, silyl, boryl, dialkyl amino, alkylthio, arylthio and seleno, with the proviso that none of R_1 , R_2 , R_3 , R_4 , R_5 , R_9 , R_{10} , R_{11} , R_{12} and R_{13} comprise fluorine; optionally two or more R groups can combine together into ring structures with such ring structures having from 3 to 100 non-hydrogen atoms in the ring; A is a bridging group having from one to 50 non-hydrogen atoms; R_a and R_b are joined to form a bridging group, E, having from one to 50 non-hydrogen atoms; and

wherein R_a and R_b are joined to form a bridging group, E, wherein said bridging group is selected from the group consisting of optionally substituted divalent hydrocarbyl and divalent heteroatom containing hydrocarbyl; or

wherein, R_a and R_b are joined to form a bridging group, E, wherein said bridging group is selected from the group consisting of optionally substituted divalent alkyl, optionally substituted divalent cycloalkyl, alkenyl, alkynyl, heteroalkyl, heterocycloalkyl, heteroalkenyl, heteroalkynyl, carbocycle, heterocarbocycle, aryl, heteroaryl and silyl; or

wherein R_a and R_b are joined to form a bridging group represented by the general formula— $(QR^{18}_{2-z'})_{z''}$ —wherein each Q is either carbon or silicon and each R^{18} may be the same or different from the others such that each R^{18} is selected from the group consisting of hydride and optionally substituted hydrocarbyl and heteroatom containing hydrocarbyl, and optionally two or more R^{18} groups may be joined into a ring structure having from 3 to 50 atoms in the ring structure not counting hydrogen atoms; z' is an integer from 1 to 10; and z'' is 0, 1 or 2.

[0006] Each of $R_1, R_2, R_3, R_4, R_5, R_6, R_7, R_8, R_9, R_{10}, R_{11}, R_{12}, R_{13}, R_{14}, R_{15}$ and R_{16} may be independently selected from the group consisting of hydride, halide, optionally substituted alkyl, heteroalkyl, aryl, heteroaryl, alkoxy, aryloxy, silyl, dialkylamino, alkylthio, and arylthio, with the proviso that none of $R_1, R_2, R_3, R_4, R_5, R_9, R_{10}, R_{11}, R_{12}$ and R_{13} comprise fluorine.

[0007] Each of $R_1, R_2, R_3, R_4, R_5, R_6, R_7, R_8, R_9, R_{10}, R_{11}, R_{12}, R_{13}, R_{14}, R_{15}$ and R_{16} may be independently selected from the group consisting of hydride, halide, optionally substituted alkyl, heteroalkyl, aryl, heteroaryl, alkoxy, and aryloxy, with the proviso that none of $R_1, R_2, R_3, R_4, R_5, R_9, R_{10}, R_{11}, R_{12}$ and R_{13} comprise fluorine.

[0008] The bridging group A may be selected from the group consisting of optionally substituted divalent hydrocarbyl and divalent heteroatom containing hydrocarbyl.

[0009] The bridging group A may be selected from the group consisting of optionally substituted divalent alkyl, alkenyl, alkynyl, heteroalkyl, heteroalkenyl, heteroalkynyl, carbocycle, heterocarbocycle, aryl, heteroaryl and silyl.

[0010] The bridging group A may be represented by the general formula— $(QR^{17}_{2-z'})_{z''}$ —wherein each Q is either carbon or silicon and each R^{17} may be the same or different from the others such that each R^{17} is selected from the group consisting of hydride and optionally substituted hydrocarbyl and heteroatom containing hydrocarbyl, and optionally two or more R^{17} groups may be joined into a ring structure having from 3 to 50 atoms in the ring structure not counting hydrogen atoms; z' is an integer from 1 to 10; and z'' is 0, 1 or 2.

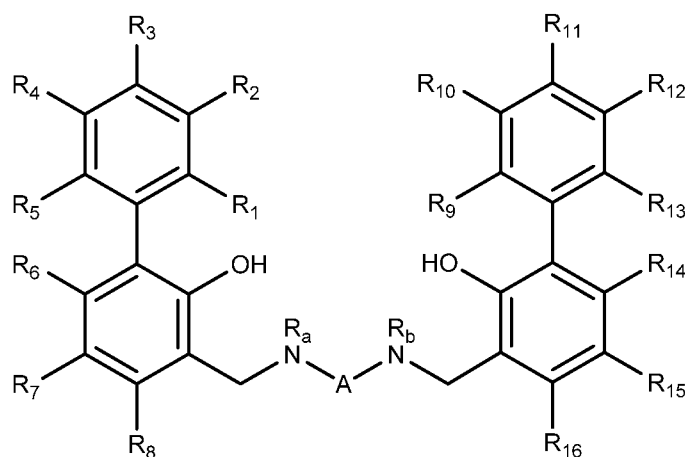
[0011] R_a and R_b may be independently selected from hydride or optionally substituted alkyl.

[0012] R_a and R_b may be joined to form a bridging group, E, wherein said bridging group may be selected from the group consisting of optionally substituted divalent hydrocarbyl and divalent heteroatom containing hydrocarbyl.

[0013] R_a and R_b may be joined to form a bridging group, E, wherein said bridging group may be selected from the group consisting of optionally substituted divalent alkyl, alkenyl, alkynyl, heteroalkyl, heteroalkenyl, heteroalkynyl, carbocycle, heterocarbocycle, aryl, heteroaryl and silyl.

[0014] R_a and R_b may be joined to form a bridging group represented by the general formula— $(QR^{18})_{2-z''}$ —wherein each Q is either carbon or silicon and each R^{18} may be the same or different from the others such that each R^{18} is selected from the group consisting of hydride and optionally substituted hydrocarbyl and heteroatom containing hydrocarbyl, and optionally two or more R^{18} groups may be joined into a ring structure having from 3 to 50 atoms in the ring structure not counting hydrogen atoms; z' is an integer from 1 to 10; and z'' is 0, 1 or 2.

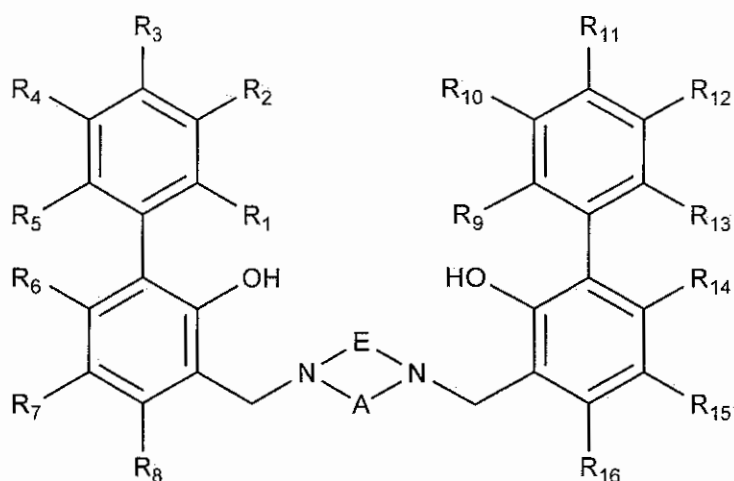
[0015] The bis(aminophenylphenol) ligand of formula (I) may be of formula (II):



(II)

wherein each of R_1 , R_2 , R_3 , R_4 , R_5 , R_6 , R_7 , R_8 , R_9 , R_{10} , R_{11} , R_{12} , R_{13} , R_{14} , R_{15} and R_{16} and A is as hereinbefore defined and R_a and R_b are independently selected from optionally substituted alkyl.

[0016] The bis(aminophenylphenol) ligand of formula (I) may be of formula (III):



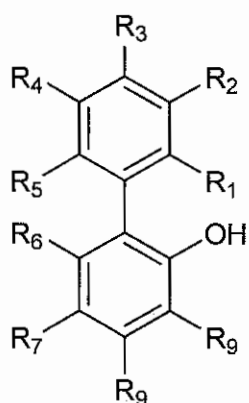
(III)

wherein each of R_1 , R_2 , R_3 , R_4 , R_5 , R_6 , R_7 , R_8 , R_9 , R_{10} , R_{11} , R_{12} , R_{13} , R_{14} , R_{15} and R_{16} is as hereinbefore defined and A and E are independently optionally substituted divalent alkyl.

[0017] The bridging groups A and E may be the same or different divalent alkyl containing from 1 to 10, or from 2 to 6 carbon atoms.

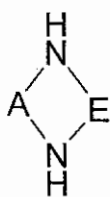
[0018] There is also provided a method for preparing a bis(aminophenylphenol) ligand of formula (I), (II) or (III) wherein the method comprises at least one step of reductive amination or Mannich aminoalkylation.

[0018a] In another aspect, there is provided a method of preparing a ligand as defined herein, wherein the method comprises at least one step of reductive amination or Mannich aminoalkylation and the step of treating an arylphenol of formula (VI):



(VI)

wherein R_1 to R_7 and R_9 , are as defined above,
with a heterocycle of formula (VII):



(VII)

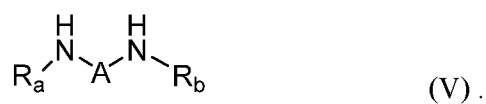
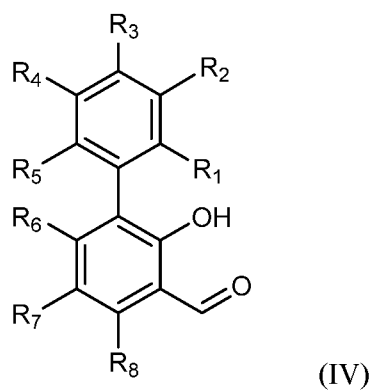
wherein A and E are as defined above,

in the presence of formaldehyde, or a source of formaldehyde, to yield the bis(aminophenylphenol) ligand of formula (I) or formula (III) as defined above.

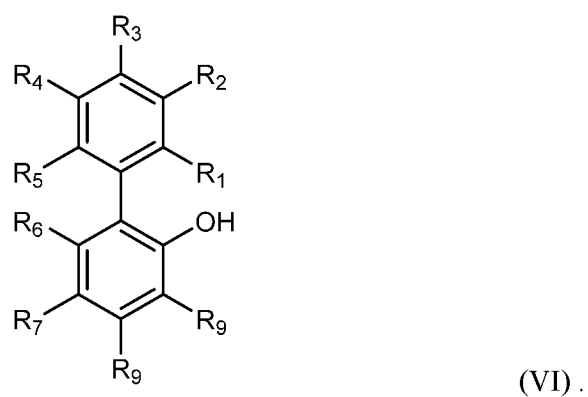
[0019] The method may also comprise at least one step of aryl coupling, such as Suzuki coupling.

[0020] The method may comprise the steps of:

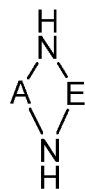
- (a) treating an arylphenol carboxaldehyde of formula (IV) with a diamine of formula (V); and
 - (b) treating the product formed in (a) with a reducing agent;
- so as to yield the bis(aminophenylphenol) ligand of formula (I) or formula (II).



[0021] The method may comprise the step of treating an arylphenol of formula (VI), with the diamine of formula (V) in the presence of formaldehyde, or a source of formaldehyde, to yield the bis(aminophenylphenol) ligand of formula (I) or formula (II)



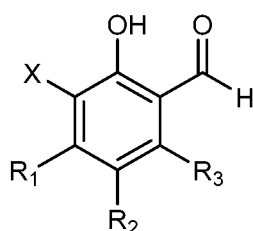
[0022] The method may comprise the step of treating an arylphenol of formula (VI), with a heterocycle of formula (VII) in the presence of formaldehyde, or a source of formaldehyde, to yield the bis(aminophenylphenol) ligand of formula (I) or formula (III)



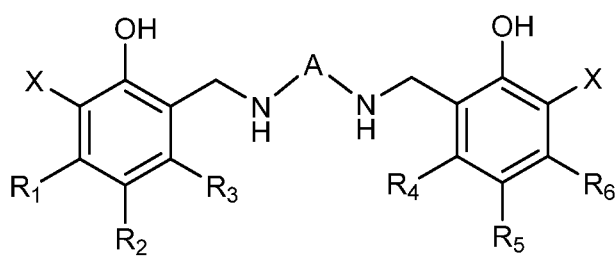
(VII) .

[0023] The method may comprise the steps of:

- a) treating a halophenol of formula (VIII) with the diamine of formula (V) so as to yield the dihalo compound of formula (IX);

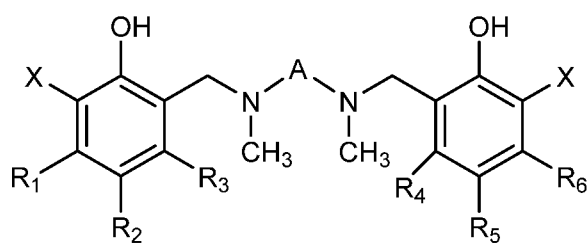


(VIII)



(IX)

- b) treating the compound of formula (IX) with formaldehyde, or a source of formaldehyde, in the presence of a reducing agent to yield a compound of formula (X);



(X)

c) treating the compound of formula (X) with an aryl-boron compound (ArBR^{c}_2 or ArBF_3M^+) in the presence of a catalyst, so as yield a compound of formula (I) or formula (II), wherein Ar is optionally substituted aryl or optionally substituted heteroaryl; R^{c} is independently selected from hydride, alkyl, hydroxy and alkoxy, wherein when both of R^{c} are alkoxy, optionally they may combine to form a ring structure of formula $\text{BO}_2\text{R}^{\text{c}}_2$, and wherein M^+ is an alkali metal cation.

[0024] In any one of the hereinbefore disclosed methods each of R_1 , R_2 , R_3 , R_4 , R_5 , R_6 , R_7 , R_8 , R_9 , R_{10} , R_{11} , R_{12} , R_{13} , R_{14} , R_{15} and R_{16} may be independently selected from the group consisting of hydride, halide, optionally substituted alkyl, heteroalkyl, aryl, heteroaryl, alkoxy, aryloxy, silyl, dialkylamino, alkylthio, and arylthio, with the proviso that none of R_1 , R_2 , R_3 , R_4 , R_5 , R_9 , R_{10} , R_{11} , R_{12} and R_{13} comprise fluorine.

[0025] In any one of the hereinbefore disclosed methods each of R_1 , R_2 , R_3 , R_4 , R_5 , R_6 , R_7 , R_8 , R_9 , R_{10} , R_{11} , R_{12} , R_{13} , R_{14} , R_{15} and R_{16} may be independently selected from the group consisting of hydride, halide, optionally substituted alkyl, heteroalkyl, aryl, heteroaryl, alkoxy, and aryloxy, with the proviso that none of R_1 , R_2 , R_3 , R_4 , R_5 , R_9 , R_{10} , R_{11} , R_{12} and R_{13} comprise fluorine.

[0026] In any one of the hereinbefore disclosed methods the bridging group A may be selected from the group consisting of optionally substituted divalent hydrocarbyl and divalent heteroatom containing hydrocarbyl.

[0027] In any one of the hereinbefore disclosed methods the bridging group A may be selected from the group consisting of optionally substituted divalent alkyl, alkenyl, alkynyl, heteroalkyl, heteroalkenyl, heteroalkynyl, carbocycle, heterocarbocycle, aryl, heteroaryl and silyl.

[0028] In any one of the hereinbefore disclosed methods the bridging group A may be represented by the general formula— $(\text{QR}^{17}_{2-z'})_{z'}$ —wherein each Q is either carbon or silicon and each R^{17} may be the same or different from the others such that each R^{17} is selected from the group consisting of hydride and optionally substituted hydrocarbyl and heteroatom containing hydrocarbyl, and optionally two or more R^{17} groups may be joined into a ring structure having from 3 to 50 atoms in the ring structure not counting hydrogen atoms; z' is an integer from 1 to 10; and z'' is 0, 1 or 2.

[0029] In any one of the hereinbefore disclosed methods R_a and R_b may be independently selected from hydride or optionally substituted alkyl.

[0030] In any one of the hereinbefore disclosed methods R_a and R_b may be joined to form a bridging group, E, wherein said bridging group may be selected from the group consisting of optionally substituted divalent hydrocarbyl and divalent heteroatom containing hydrocarbyl.

[0031] In any one of the hereinbefore disclosed methods R_a and R_b may be joined to form a bridging group, E, wherein said bridging group may be selected from the group consisting of optionally substituted divalent alkyl, alkenyl, alkynyl, heteroalkyl, heteroalkenyl, heteroalkynyl, carbocycle, heterocarbocycle, aryl, heteroaryl and silyl.

[0032] In any one of the hereinbefore disclosed methods R_a and R_b may be joined to form a bridging group represented by the general formula— $(QR^{18}_{2-z''})_z$ —wherein each Q is either carbon or silicon and each R^{18} may be the same or different from the others such that each R^{18} is selected from the group consisting of hydride and optionally substituted hydrocarbyl and heteroatom containing hydrocarbyl, and optionally two or more R^{18} groups may be joined into a ring structure having from 3 to 50 atoms in the ring structure not counting hydrogen atoms; z' is an integer from 1 to 10; and z'' is 0, 1 or 2.

[0033] In any one of the hereinbefore disclosed embodiments the catalyst may comprise a nickel or palladium catalyst.

[0034] In any one of the hereinbefore disclosed embodiments the palladium catalyst may comprise a palladium phosphine catalyst. The palladium catalyst may also comprise, for example, bis(tri-tert-butylphosphine)palladium, tetrakis(triphenylphosphine)palladium(0) ($Pd(PPh_3)_4$), bis[1,2-bis(diphenylphosphino)ethane]palladium(0) ($Pd(dppe)_2$), 1,1'-bis(diphenylphosphino)ferrocene palladium ($Pd(dppf)$), (2,2'-bis(diphenylphosphino)-1,1'-binaphthyl palladium ($Pd(BINAP)$).

[0035] In any one of the hereinbefore disclosed embodiments the reducing agent may be a metal hydride. A non-limiting example includes sodium borohydride.

[0036] The herein disclosed methods may comprise any combination of the hereinbefore disclosed embodiments.

[0037] The present disclosure provides a ligand of formula (I), (II) or (III) prepared by any one of the hereinbefore disclosed methods.

[0038] The present disclosure further provides a transition metal compound formed from any one of the ligands of formula (I), (II) or (III). The transition metal compounds may comprise a titanium, a zirconium or a hafnium atom.

[0038a] In another aspect, there is provided a transition metal compound comprising a ligand as defined herein, wherein the transition metal compound comprises one or more titanium, zirconium or hafnium atoms.

[0039] In another aspect there is provided a catalyst composition comprising one or more transition metal compounds as hereinbefore disclosed, and one or more activators. The activator may comprise one or more alumoxanes. The activator may comprise methylalumoxane.

[0040] In another aspect there is provided a supported catalyst composition comprising one or more transition metal compounds as hereinbefore disclosed, one or more activators and one or more support materials. The activator may comprise one or more alumoxanes. The activator may comprise methylalumoxane. The support may be silica.

[0041] The catalyst composition or supported catalyst composition may comprise two or more transition metal compounds. The transition metal compounds may be selected from any one of those hereinbefore described or at least one of the transition metal compounds may be different from those hereinbefore described. For example, at least one of the transition metal compounds may be a metallocene.

[0042] The present disclosure further provides a process for polymerizing olefins, the process comprising:

contacting olefins with one or more catalyst compositions or supported catalyst compositions comprising at least one transition metal compound as hereinbefore disclosed in a reactor under polymerization conditions to produce an olefin polymer or copolymer.

[0042a] In another aspect, there is provided a process for polymerizing olefins, the process comprising:

contacting olefins with one or more catalyst compositions or supported catalyst compositions as defined herein in a reactor under polymerization conditions to produce an olefin polymer or copolymer.

BRIEF DESCRIPTION OF THE DRAWINGS

[0043] Figure 1 depicts the chemical structures of exemplary compounds in accordance with this disclosure.

[0044] Figures 2 to 6 depict exemplary reaction schemes in accordance with this disclosure.

DETAILED DESCRIPTION

[0045] Before the present compounds, components, compositions, and/or methods are disclosed and described, it is to be understood that unless otherwise indicated this invention is not limited to specific compounds, components, compositions, reactants, reaction conditions, ligands, transition metal compounds, or the like, as such may vary, unless otherwise specified. It is also to be understood that the terminology used herein is for the purpose of describing particular embodiments only and is not intended to be limiting.

[0046] It must also be noted that, as used in the specification and the appended claims, the singular forms "a," "an" and "the" include plural referents unless otherwise specified. Thus, for example, reference to "a halogen atom" as in a moiety "substituted with a halogen atom" includes more than one halogen atom, such that the moiety may be substituted with two or more halogen atoms, reference to "a substituent" includes one or more substituents, reference to "a ligand" includes one or more ligands, and the like.

[0047] As used herein, all reference to the Periodic Table of the Elements and groups thereof is to the NEW NOTATION published in HAWLEY'S CONDENSED CHEMICAL DICTIONARY, Thirteenth Edition, John Wiley & Sons, Inc., (1997) (reproduced there with

permission from IUPAC), unless reference is made to the Previous IUPAC form noted with Roman numerals (also appearing in the same), or unless otherwise noted.

General Definitions

[0048] As used herein, a "catalyst composition" includes one or more catalyst compounds utilized to polymerize olefins and one or more activators or, alternatively, one or more cocatalysts. The catalyst composition may include any suitable number of catalyst compounds in any combination as described herein, as well as any activator or cocatalyst in any combination as described herein.

[0049] As used herein, a "supported catalyst composition" includes one or more catalyst compounds utilized to polymerize olefins and one or more activators or, alternatively, one or more cocatalysts, and one or more supports. The supported catalyst composition may include any suitable number of catalyst compounds in any combination as described herein, as well as any activator or cocatalyst in any combination as described herein. A "supported catalyst composition" may also contain one or more additional components known in the art to reduce or eliminate reactor fouling such as continuity additives.

[0050] As used herein, a "catalyst compound" may include any compound that, when activated, is capable of catalyzing the polymerization or oligomerization of olefins, wherein the catalyst compound comprises at least one Group 3 to 12 atom, and optionally at least one leaving group bound thereto.

[0051] The term "independently selected" is used herein to indicate that the R groups, e.g., R¹, R², R³, R⁴, and R⁵ can be identical or different (e.g. R¹, R², R³, R⁴, and R⁵ may all be substituted alkyls or R¹ and R² may be a substituted alkyl and R³ may be an aryl, etc.). Use of the singular includes use of the plural and vice versa (e.g., a hexane solvent, includes hexanes). A named R group will generally have the structure that is recognized in the art as corresponding to R groups having that name. The terms "compound" and "complex" are generally used interchangeably in this specification, but those of skill in the art may recognize certain compounds as complexes and vice versa. For the purposes of illustration, representative certain groups are defined herein. These definitions are intended to supplement and illustrate, not preclude, the definitions known to those of skill in the art.

[0052] "Optional" or "optionally" means that the subsequently described event or circumstance may or may not occur, and that the description includes instances where said event or circumstance occurs and instances where it does not. For example, the phrase "optionally substituted hydrocarbyl" means that a hydrocarbyl moiety may or may not be substituted and

that the description includes both unsubstituted hydrocarbyl and hydrocarbyl where there is substitution.

[0053] The term "alkyl" as used herein refers to a branched or unbranched saturated hydrocarbon group typically although not necessarily containing 1 to about 50 carbon atoms, such as methyl, ethyl, n-propyl, isopropyl, n-butyl, iso-butyl, t-butyl, octyl, decyl, and the like, as well as cycloalkyl groups such as cyclopentyl, cyclohexyl and the like. Generally, although again not necessarily, alkyl groups herein may contain 1 to about 12 carbon atoms. The term "lower alkyl" intends an alkyl group of one to six carbon atoms, specifically one to four carbon atoms. "Substituted alkyl" refers to alkyl substituted with one or more substituent groups (e.g., benzyl or chloromethyl), and the terms "heteroatom-containing alkyl" and "heteroalkyl" refer to alkyl in which at least one carbon atom is replaced with a heteroatom (e.g., $-\text{CH}_2\text{OCH}_3$ is an example of a heteroalkyl).

[0054] The term "alkenyl" as used herein refers to a branched or unbranched hydrocarbon group typically although not necessarily containing 2 to about 50 carbon atoms and at least one double bond, such as ethenyl, n-propenyl, iso-propenyl, n-butenyl, iso-butenyl, octenyl, decenyl, and the like. Generally, although again not necessarily, alkenyl groups herein contain 2 to about 12 carbon atoms. The term "lower alkenyl" refers to an alkenyl group of two to six carbon atoms, specifically two to four carbon atoms. "Substituted alkenyl" refers to alkenyl substituted with one or more substituent groups, and the terms "heteroatom-containing alkenyl" and "heteroalkenyl" refer to alkenyl in which at least one carbon atom is replaced with a heteroatom.

[0055] The term "alkynyl" as used herein refers to a branched or unbranched hydrocarbon group typically although not necessarily containing 2 to about 50 carbon atoms and at least one triple bond, such as ethynyl, n-propynyl, iso-propynyl, n-butylnyl, isobutylnyl, octynyl, decynyl, and the like. Generally, although again not necessarily, alkynyl groups herein may have 2 to about 12 carbon atoms. The term "lower alkynyl" refers to an alkynyl group of two to six carbon atoms, specifically three or four carbon atoms. "Substituted alkynyl" refers to alkynyl substituted with one or more substituent groups, and the terms "heteroatom-containing alkynyl" and "heteroalkynyl" refer to alkynyl in which at least one carbon atom is replaced with a heteroatom.

[0056] The term "alkoxy" as used herein intends an alkyl group bound through a single, terminal ether linkage; that is, an "alkoxy" group may be represented as $-\text{O-alkyl}$ where alkyl is as defined above. A "lower alkoxy" group refers to an alkoxy group having one to six, more specifically one to four, carbon atoms. The term "aryloxy" is used in a similar fashion, with aryl as defined below. The term "hydroxy" refers to $-\text{OH}$.

[0057] Similarly, the term "alkylthio" as used herein intends an alkyl group bound through a single, terminal thioether linkage; that is, an "alkylthio" group may be represented as -S-alkyl where alkyl is as defined above. A "lower alkyl thio" group refers to an alkyl thio group having one to six, more specifically one to four, carbon atoms. The term "arylthio" is used similarly, with aryl as defined below. The term "thioxy" refers to -SH.

[0058] The term "allenyl" is used herein in the conventional sense to refer to a molecular segment having the structure $-\text{CH}=\text{C}=\text{CH}_2$. An "allenyl" group may be unsubstituted or substituted with one or more non-hydrogen substituents.

[0059] The term "aryl" as used herein, and unless otherwise specified, refers to an aromatic substituent containing a single aromatic ring or multiple aromatic rings that are fused together, linked covalently, or linked to a common group such as a methylene or ethylene moiety. More specific aryl groups contain one aromatic ring or two or three fused or linked aromatic rings, e.g., phenyl, naphthyl, biphenyl, anthracenyl, phenanthrenyl, and the like. The aryl substituents may have 1 to about 200 carbon atoms, typically 1 to about 50 carbon atoms, and specifically 1 to about 20 carbon atoms. "Substituted aryl" refers to an aryl moiety substituted with one or more substituent groups, (e.g., tolyl, mesityl and perfluorophenyl) and the terms "heteroatom-containing aryl" and "heteroaryl" refer to aryl in which at least one carbon atom is replaced with a heteroatom (e.g., rings such as thiophene, pyridine, isoxazole, pyrazole, pyrrole, furan, etc. or benzo-fused analogues of these rings are included in the term "heteroaryl"). In some embodiments herein, multi-ring moieties are substituents and in such an embodiment the multi-ring moiety can be attached at an appropriate atom. For example, "naphthyl" can be 1-naphthyl or 2-naphthyl; "anthracenyl" can be 1-anthracenyl, 2-anthracenyl or 9-anthracenyl; and "phenanthrenyl" can be 1-phenanthrenyl, 2-phenanthrenyl, 3-phenanthrenyl, 4-phenanthrenyl or 9-phenanthrenyl.

[0060] The term "aralkyl" refers to an alkyl group with an aryl substituent, and the term "aralkylene" refers to an alkylene group with an aryl substituent; the term "alkaryl" refers to an aryl group that has an alkyl substituent, and the term "alkarylene" refers to an arylene group with an alkyl substituent.

[0061] The terms "halo" and "halogen" are used in the conventional sense to refer to a chloro, bromo, fluoro or iodo substituent. The terms "haloalkyl," "haloalkenyl" or "haloalkynyl" (or "halogenated alkyl," "halogenated alkenyl," or "halogenated alkynyl") refers to an alkyl, alkenyl or alkynyl group, respectively, in which at least one of the hydrogen atoms in the group has been replaced with a halogen atom.

[0062] The term "heteroatom-containing" as in a "heteroatom-containing hydrocarbyl group" refers to a molecule or molecular fragment in which one or more carbon atoms is replaced with an atom other than carbon, e.g., nitrogen, oxygen, sulfur, phosphorus, boron or silicon. Similarly, the term "heteroalkyl" refers to an alkyl substituent that is heteroatom-containing, the term "heterocyclic" refers to a cyclic substituent that is heteroatom-containing, the term "heteroaryl" refers to an aryl substituent that is heteroatom-containing, and the like. When the term "heteroatom-containing" appears prior to a list of possible heteroatom-containing groups, it is intended that the term apply to every member of that group. That is, the phrase "heteroatom-containing alkyl, alkenyl and alkynyl" is to be interpreted as "heteroatom-containing alkyl, heteroatom-containing alkenyl and heteroatom-containing alkynyl."

[0063] "Hydrocarbyl" refers to hydrocarbyl radicals containing 1 to about 50 carbon atoms, specifically 1 to about 24 carbon atoms, most specifically 1 to about 16 carbon atoms, including branched or unbranched, saturated or unsaturated species, such as alkyl groups, alkenyl groups, aryl groups, and the like. The term "lower hydrocarbyl" refers to a hydrocarbyl group of one to six carbon atoms, specifically one to four carbon atoms. "Substituted hydrocarbyl" refers to hydrocarbyl substituted with one or more substituent groups, and the terms "heteroatom-containing hydrocarbyl" and "heterohydrocarbyl" refer to hydrocarbyl in which at least one carbon atom is replaced with a heteroatom.

[0064] By "substituted" as in "substituted hydrocarbyl," "substituted aryl," "substituted alkyl," "substituted alkenyl" and the like, as alluded to in some of the aforementioned definitions, is meant that in the hydrocarbyl, hydrocarbylene, alkyl, alkenyl, aryl or other moiety, at least one hydrogen atom bound to a carbon atom is replaced with one or more substituents that are functional groups such as hydroxyl, alkoxy, alkylthio, phosphino, amino, halo, silyl, and the like. When the term "substituted" appears prior to a list of possible substituted groups, it is intended that the term apply to every member of that group. That is, the phrase "substituted alkyl, alkenyl and alkynyl" is to be interpreted as "substituted alkyl, substituted alkenyl and substituted alkynyl." Similarly, "optionally substituted alkyl, alkenyl and alkynyl" is to be interpreted as "optionally substituted alkyl, optionally substituted alkenyl and optionally substituted alkynyl."

[0065] By "divalent" as in "divalent hydrocarbyl", "divalent alkyl", "divalent aryl" and the like, is meant that the hydrocarbyl, alkyl, aryl or other moiety is bonded at two points to atoms, molecules or moieties with the two bonding points being covalent bonds. The term "aromatic" is used in its usual sense, including unsaturation that is essentially delocalized across multiple bonds, such as around a ring.'

[0066] As used herein the term "silyl" refers to the $-\text{SiZ}^1\text{Z}^2\text{Z}^3$ radical, where each of Z^1 , Z^2 , and Z^3 is independently selected from the group consisting of hydride and optionally substituted alkyl, alkenyl, alkynyl, heteroatom-containing alkyl, heteroatom-containing alkenyl, heteroatom-containing alkynyl, aryl, heteroaryl, alkoxy, aryloxy, amino, silyl and combinations thereof.

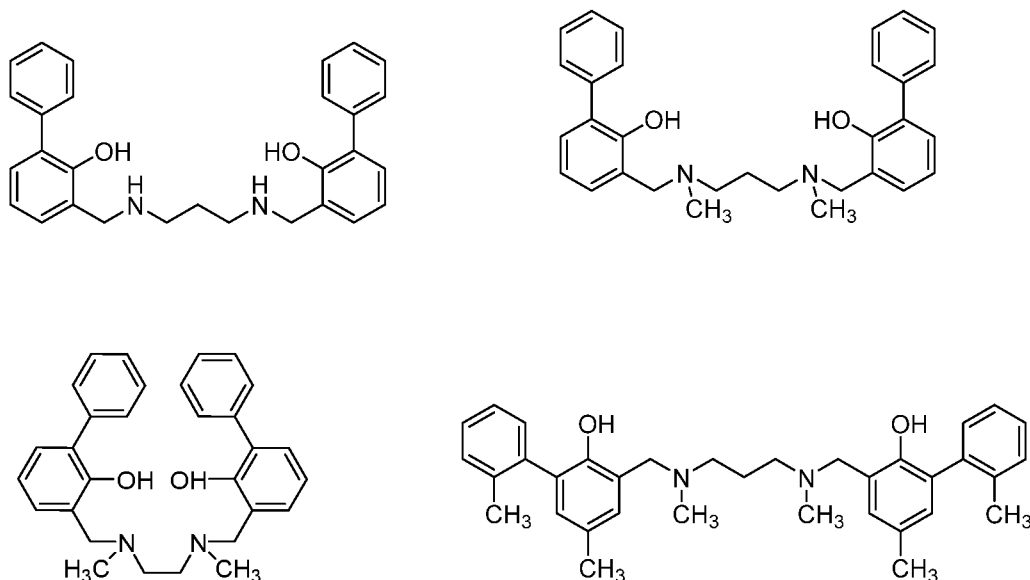
[0067] As used herein the term "boryl" refers to the $-\text{BZ}^1\text{Z}^2$ group, where each of Z^1 and Z^2 is as defined above.

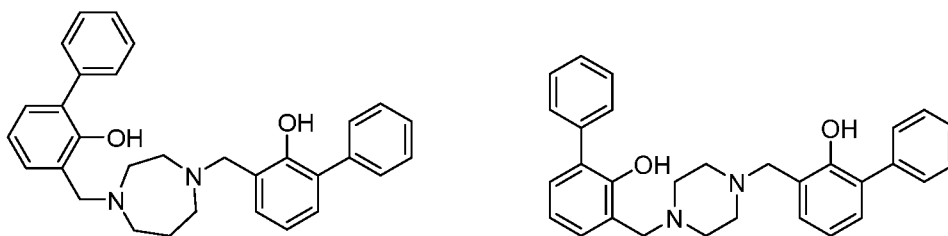
[0068] The term "amino" is used herein to refer to the group $-\text{NZ}^1\text{Z}^2$, where each of Z^1 and Z^2 is as defined above. The term "amine" is used herein to refer to the group $\text{NZ}^1\text{Z}^2\text{Z}^3$, where each of Z^1 , Z^2 and Z^3 is as defined above.

[0069] The term "saturated" refers to lack of double and triple bonds between atoms of a radical group such as ethyl, cyclohexyl, pyrrolidinyl, and the like. The term "unsaturated" refers to the presence of one or more double and triple bonds between atoms of a radical group such as vinyl, acetylide, oxazoliny, cyclohexenyl, acetyl and the like.

[0070] Other abbreviations used herein include: "iPr" to refer to isopropyl; "tBu" to refer to tertbutyl; "Me" to refer to methyl; "Et" to refer to ethyl; and "Ph" refers to phenyl.

[0071] Specific ligands disclosed herein include:



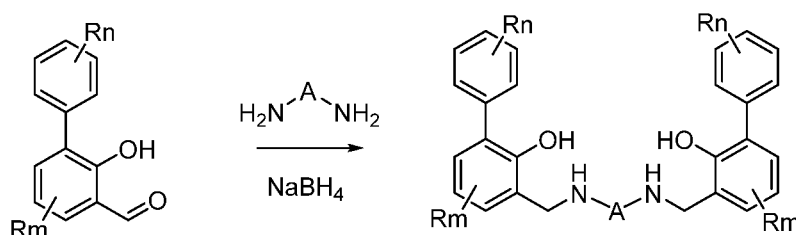


Ligand Synthesis

[0072] The ligands disclosed herein may be prepared by a variety of methods. In general the ligands may be prepared by employing reductive amination or Mannich aminomethylation reactions.

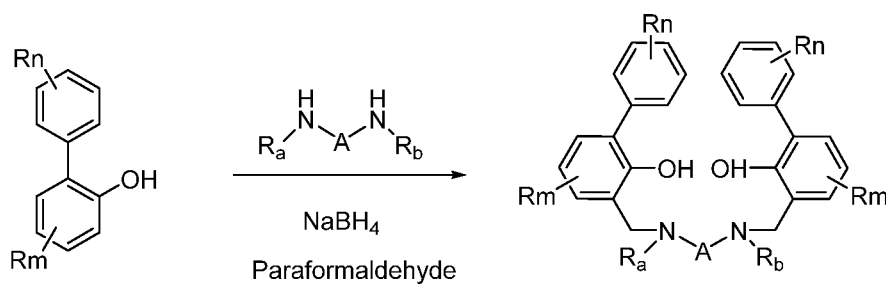
[0073] The following schemes illustrate general methods for the preparation of the ligands.

[0074] In Scheme 1 an aryl phenol carboxaldehyde may be reductively aminated with a diamine.



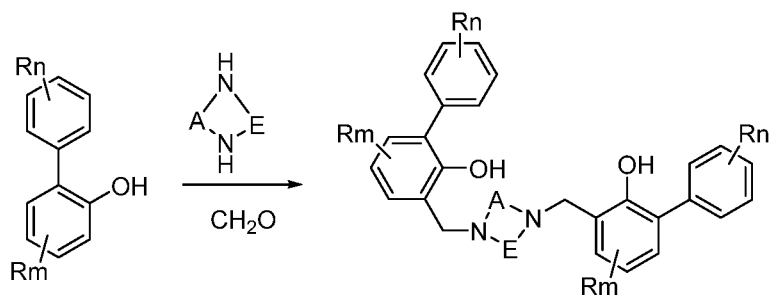
Scheme 1

[0075] Scheme 2 illustrates Mannich aminomethylation of an aryl phenol



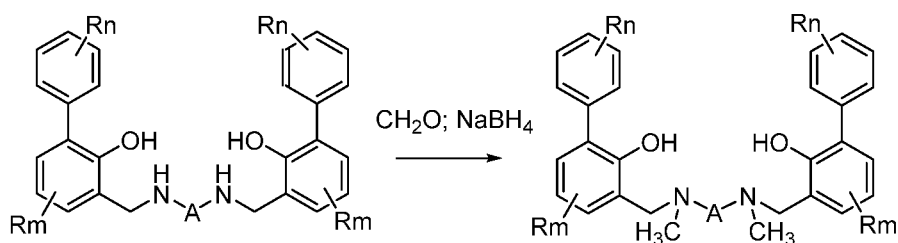
Scheme 2

[0076] In Scheme 3 a similar aminomethylation reaction may be performed with a heterocyclic amine.



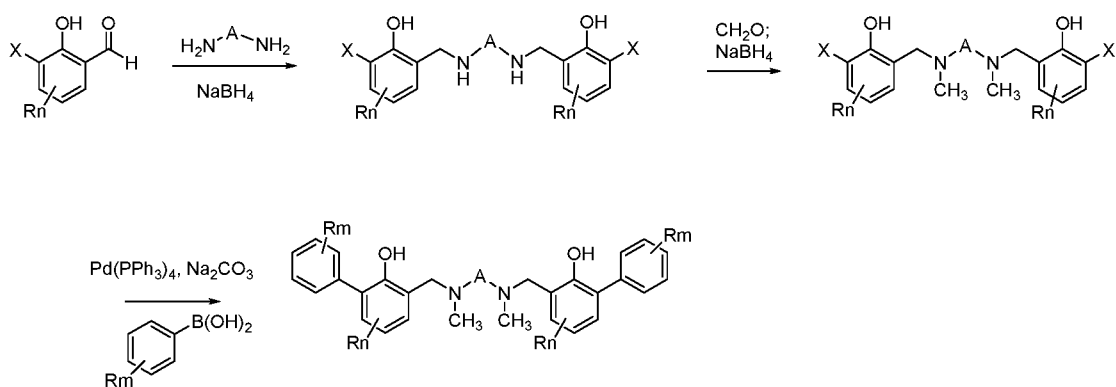
Scheme 3

[0077] Scheme 4 illustrates methylation.



Scheme 4

[0078] Scheme 5 illustrates first forming a halogenated aminophenol, followed by aryl coupling.



Scheme 5

In any one of the above methods each of Rn and Rm is independently selected from the group consisting of hydride, halide, optionally substituted hydrocarbyl, heteroatom-containing optionally substituted hydrocarbyl, alkoxy, aryloxy, silyl, boryl, dialkyl amino, alkylthio,

arylthio and seleno, with the proviso that R_n and R_m do not comprise fluorine; optionally two or more R_n or R_m groups can combine together into ring structures with such ring structures having from 3 to 100 non-hydrogen atoms in the ring; A and E are bridging groups having from one to 50 non-hydrogen atoms; R_a and R_b are independently selected from hydride or optionally substituted hydrocarbyl; X is halide, preferably bromide.

[0079] In Scheme 5 the aryl coupling may be Suzuki coupling. In Scheme 5 the palladium catalyst may also comprise alternative palladium phosphine compounds, for example, bis(tri-tert-butylphosphine)palladium, bis[1,2-bis(diphenylphosphino)ethane]palladium(0), 1,1'-bis(diphenylphosphino)ferrocene palladium, and (2,2'-bis(diphenylphosphino)-1,1'-binaphthyl)palladium.

[0080] In an illustrative embodiment and referring to the structures in Figure 1 and the reaction scheme in Figure 2; to phenyl phenol carboxaldehyde in methanol was added diaminopropane. Treatment with sodium borohydride afforded 3,3'-((propane-1,3-diylbis(azanediyl))bis(methylene))bis([1,1'-biphenyl]-2-ol) (1). Subsequent treatment of (1) with formaldehyde followed by sodium borohydride afforded 3,3'-((propane-1,3-diylbismethylazanediyl)bis(methylene))bis([1,1'-biphenyl]-2-ol) (2).

[0081] Figures 3 to 6 illustrate further exemplary reaction schemes.

Catalyst Compounds

[0082] The catalyst compounds may be prepared by any suitable synthesis method and the method of synthesis is not critical to the present disclosure. One useful method of preparing the catalyst compounds of the present disclosure is by reacting a suitable metal compound, for example one having a displaceable anionic ligand, with the bridged bi-aromatic ligands of this disclosure. Non-limiting examples of suitable metal compounds include organometallics, metal halids, sulfonates, carboxylates, phosphates, organoborates (including fluoro-containing and other subclasses), acetonacetates, sulfides, sulfates, tetrafluoroborates, nitrates, perchlorates, phenoxides, alkoxides, silicates, arsenates, borohydrides, naphthenates, cyclooctadienes, diene conjugated complexes, thiocyanates, cyanates, and the metal cyanides. The metal compound may be an organometallic or metal halide. The metal compound may be an organometallic.

[0083] The metal of the organometallic compound may be selected from Groups 1 to 16, or a transition metal selected from Groups 3 to 13 elements and Lanthanide series elements. The metal may be selected from Groups 3 to 7 elements. The metal may be a Group 4 metal, titanium, zirconium or hafnium.

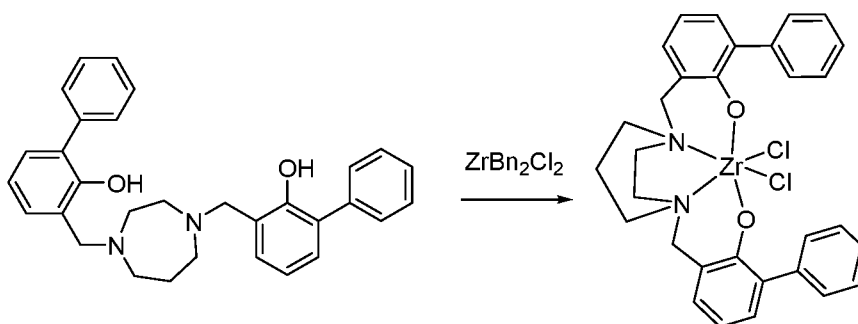
[0084] The metal compound can, for example, be a metal hydrocarbyl such as: a metal alkyl, a metal aryl, a metal arylalkyl; a metal silylalkyl; a metal diene, a metal amide; or a metal

phosphide. The metal compound may be a zirconium or hafnium hydrocarbyl. The transition metal compound may be a zirconium arylalkyl.

[0085] Examples of useful and preferred metal compounds include:

- (i) tetramethylzirconium, tetraethylzirconium, zirconiumdichloride (η^4 -1,4-diphenyl-1,3-butadiene), bis (triethylphosphine) and zirconiumdichloride (η^4 -1,4-diphenyl-1,3-butadiene) bis (tri-n-propylphosphine), tetrakis[trimethylsilylmethyl]zirconium, tetrakis[dimethylamino]zirconium, dichlorodibenzylzirconium, chlorotribenzylzirconium, trichlorobenzylzirconium, bis[dimethylamino]bis[benzyl]zirconium, and tetrabenzylzirconium;
- (ii) tetramethyltitanium, tetraethyltitanium, titaniumdichloride (η^4 -1,4-diphenyl-1,3-butadiene), bis (triethylphosphine) and titaniumdichloride (η^4 -1,4-diphenyl-1,3-butadiene) bis (tri-n-propylphosphine), tetrakis[trimethylsilylmethyl]titanium, tetrakis[dimethylamino]titanium, dichlorodibenzyltitanium, chlorotribenzyltitanium, trichlorobenzyltitanium, bis[dimethylamino]bis[benzyl]titanium, and tetrabenzyltitanium; and
- (iii) tetramethylhafnium, tetraethylhafnium, hafniumdichloride (η^4 -1,4-diphenyl-1,3-butadiene), bis (triethylphosphine) and hafniumdichloride (η^4 -1,4-diphenyl-1,3-butadiene) bis (tri-n-propylphosphine), tetrakis[trimethylsilylmethyl]hafnium, tetrakis[dimethylamino]hafnium, dichlorodibenzylhafnium, chlorotribenzylhafnium, trichlorobenzylhafnium, bis[dimethylamino]bis[benzyl]hafnium, and tetrabenzylhafnium.

[0086] An exemplary reactions is shown below:



Catalyst and Supported Catalyst Compositions

[0087] The catalyst compositions disclosed herein may comprise one or more activators as disclosed herein and one or more catalyst compounds as disclosed herein.

[0088] The supported catalyst compositions as disclosed herein may comprise one or more supports as disclosed herein, one or more activators as disclosed herein, and one or more catalyst compounds as disclosed herein.

[0089] The catalyst compositions and supported catalyst compositions may comprise one or more of the catalyst compounds as hereinbefore disclosed along with another catalyst compound, such as a metallocene catalyst compound or a Group V atom containing catalyst compound. Suitable other catalyst compounds include, but are not limited to:

(pentamethylcyclopentadienyl)(propylcyclopentadienyl)MX₂,

(tetramethylcyclopentadienyl)(propylcyclopentadienyl)MX₂,

(tetramethylcyclopentadienyl)(butylcyclopentadienyl)MX₂,

Me₂Si(indenyl)₂MX₂,

Me₂Si(tetrahydroindenyl)₂MX₂,

(n-propyl cyclopentadienyl)₂MX₂,

(n-butyl cyclopentadienyl)₂MX₂,

(1-methyl, 3-butyl cyclopentadienyl)₂MX₂,

HN(CH₂CH₂N(2,4,6-Me₃phenyl))₂MX₂,

HN(CH₂CH₂N(2,3,4,5,6-Me₅phenyl))₂MX₂,

(propyl cyclopentadienyl)(tetramethylcyclopentadienyl)MX₂,

(butyl cyclopentadienyl)₂MX₂,

(propyl cyclopentadienyl)₂MX₂, and mixtures thereof,

wherein M is Zr or Hf, and X is selected from F, Cl, Br, I, Me, benzyl, CH₂SiMe₃, and C₁ to C₅ alkyls or alkenyls.

[0090] The supported catalyst composition may in the form of a substantially dry powder or be in the form of a slurry in at least one liquid vehicle. Non-limiting examples of liquid vehicles include mineral oils, aromatic hydrocarbons or aliphatic hydrocarbons.

Activator Compounds

[0091] An activator is defined in a broad sense as any combination of reagents that increases the rate at which a transition metal compound oligomerizes or polymerizes unsaturated monomers, such as olefins. The catalyst compounds may be activated for oligomerization and/or polymerization catalysis in any manner sufficient to allow coordination or cationic oligomerization and/or polymerization.

[0092] Additionally, the activator may be a Lewis-base, such as for example, diethyl ether, dimethyl ether, ethanol, or methanol. Other activators that may be used include those described in WO 98/07515 such as tris (2,2',2''- nonafluorobiphenyl) fluoroaluminate.

[0093] Combinations of activators may be used. For example, alumoxanes and ionizing activators may be used in combinations, see for example, EP-B1 0 573 120, WO 94/07928 and WO 95/14044 and U.S. Pat. Nos. 5,153,157 and 5,453,410. WO 98/09996 describes activating metallocene catalyst compounds with perchlorates, periodates and iodates including their hydrates. WO 98/30602 and WO 98/30603 describe the use of lithium (2,2'-bisphenyl-ditrimethylsilicate).4THF as an activator for a metallocene catalyst compound. WO 99/18135 describes the use of organo-boron-aluminum activators. EP-B1-0 781 299 describes using a silylium salt in combination with a non-coordinating compatible anion. WO 2007/024773 suggests the use of activator-supports which may comprise a chemically-treated solid oxide, clay mineral, silicate mineral, or any combination thereof. Also, methods of activation such as using radiation (see EP-B1-0 615 981), electro-chemical oxidation, and the like are also contemplated as activating methods for the purposes of rendering the neutral metallocene catalyst compound or precursor to a metallocene cation capable of polymerizing olefins. Other activators or methods for activating a metallocene catalyst compound are described in, for example, U.S. Pat. Nos. 5,849,852, 5,859,653 and 5,869,723 and PCT WO 98/32775.

[0094] Alumoxanes may also be utilized as an activator in the catalyst composition. Alumoxanes are generally oligomeric compounds containing --Al(R)--O-- subunits, where R is an alkyl group. Examples of alumoxanes include methylalumoxane (MAO), modified methylalumoxane (MMAO), ethylalumoxane and isobutylalumoxane. Alkylalumoxanes and modified alkylalumoxanes are suitable as catalyst activators, particularly when the abstractable ligand is a halide. Mixtures of different alumoxanes and modified alumoxanes may also be used. For further descriptions, see U.S. Pat. Nos. 4,665,208, 4,952,540, 5,041,584, 5,091,352, 5,206,199, 5,204,419, 4,874,734, 4,924,018, 4,908,463, 4,968,827, 5,329,032, 5,248,801, 5,235,081, 5,157,137, 5,103,031 and EP 0 561 476 A1, EP 0 279 586 B1, EP 0 516 476 A, EP 0 594 218 A1 and WO 94/10180.

[0095] 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. MMAO's are generally more soluble in aliphatic solvents and more stable during storage. There are a variety of methods for preparing alumoxane and modified alumoxanes, non-limiting examples of which are described in, for example, U.S. Pat. Nos. 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, WO 94/10180 and WO 99/15534. A visually clear methylalumoxane may be used. A cloudy or gelled alumoxane can be filtered to produce a clear solution or clear alumoxane can be decanted from the cloudy solution. Another alumoxane is a modified methyl alumoxane (MMAO) cocatalyst type 3A (commercially available from Akzo Chemicals, Inc. under the trade name Modified Methylalumoxane type 3A, disclosed in U.S. Pat. No. 5,041,584).

[0096] An ionizing or stoichiometric activator, neutral or ionic, such as tri (n-butyl) ammonium tetrakis (pentafluorophenyl) boron, a trisperfluorophenyl boron metalloid precursor or a trisperfluoronaphthyl boron metalloid precursor, polyhalogenated heteroborane anions (see, for example, WO 98/43983), boric acid (see, for example, U.S. Pat. No. 5,942,459) or combinations thereof, may also be used. The neutral or ionic activators may be used alone or in combination with alumoxane or modified alumoxane activators.

[0097] Examples of neutral stoichiometric activators may include tri-substituted boron, tellurium, aluminum, gallium and indium or mixtures thereof. The three substituent groups may be each independently selected from the group of alkyls, alkenyls, halogen, substituted alkyls, aryls, arylhalides, alkoxy and halides. The three substituent groups may be independently selected from the group of halogen, mono or multicyclic (including halosubstituted) aryls, alkyls, and alkenyl compounds and mixtures thereof; or alkenyl groups having 1 to 20 carbon atoms, alkyl groups having 1 to 20 carbon atoms, alkoxy groups having 1 to 20 carbon atoms and aryl groups having 3 to 20 carbon atoms (including substituted aryls). Alternatively, the three groups are alkyls having 1 to 4 carbon groups, phenyl, naphthyl or mixtures thereof. The three groups may be halogenated, for example fluorinated, aryl groups. In yet other illustrative examples, the neutral stoichiometric activator is trisperfluorophenyl boron or trisperfluoronaphthyl boron.

[0098] Ionic stoichiometric activator compounds may contain an active proton, or some other cation associated with, but not coordinated to, or only loosely coordinated to, the remaining ion of the ionizing compound. Such compounds and the like are described in, for example, European publications EP-A-0 570 982, EP-A-0 520 732, EP-A-0 495 375, EP-B1-0 500 944, EP-A-0 277 003 and EP-A-0 277 004, and U.S. Pat. Nos. 5,153,157, 5,198,401, 5,066,741, 5,206,197, 5,241,025, 5,384,299 and 5,502,124.

Supports

[0099] The above described catalyst compounds may be combined with one or more supports using one of the support methods well known in the art or as described below. For

example, the catalyst compound may be used in a supported form, such as, deposited on, contacted with, or incorporated within, adsorbed or absorbed in, or on the support.

[00100] As used herein, the term “support” refers to compounds comprising Group 2, 3, 4, 5, 13 and 14 oxides and chlorides. Suitable supports include, for example, silica, magnesia, titania, zirconia, montmorillonite, phyllosilicate, alumina, silica-alumina, silica-chromium, silica-titania, magnesium chloride, graphite, magnesia, titania, zirconia, montmorillonite, phyllosilicate, and the like.

[00101] The support may possess an average particle size in the range of from about 0.1 to about 500 μm , or from about 1 to about 200 μm , or from about 1 to about 50 μm , or from about 5 to about 50 μm .

[00102] The support may have an average pore size in the range of from about 10 to about 1000 $\text{\AA}$, or about 50 to about 500 $\text{\AA}$, or 75 to about 350 $\text{\AA}$.

[00103] The support may have a surface area in the range of from about 10 to about 700 m^2/g , or from about 50 to about 500 m^2/g , or from about 100 to about 400 m^2/g .

[00104] The support may have a pore volume in the range of from about 0.1 to about 4.0 cc/g , or from about 0.5 to about 3.5 cc/g , or from about 0.8 to about 3.0 cc/g .

[00105] The support, such as an inorganic oxide, may have a surface area in the range of from about 10 to about 700 m^2/g , a pore volume in the range of from about 0.1 to about 4.0 cc/g , and an average particle size in the range of from about 1 to about 500 μm . Alternatively, the support may have a surface area in the range of from about 50 to about 500 m^2/g , a pore volume of from about 0.5 to about 3.5 cc/g , and an average particle size of from about 10 to about 200 μm . The surface area of the support may be in the range from about 100 to about 400 m^2/g , a pore volume of from about 0.8 to about 3.0 cc/g and an average particle size of from about 5 to about 100 μm .

[00106] The catalyst compounds may be supported on the same or separate supports together with an activator, or the activator may be used in an unsupported form, or may be deposited on a support different from the supported catalyst compound.

[00107] There are various other methods in the art for supporting a polymerization catalyst compound. For example, the catalyst compound may contain a polymer bound ligand as described in, for example, U.S. Pat. Nos. 5,473,202 and 5,770,755; the catalyst may be spray dried as described in, for example, U.S. Pat. No. 5,648,310; the support used with the catalyst may be functionalized as described in European publication EP-A-0 802 203, or at least one substituent or leaving group is selected as described in U.S. Pat. No. 5,688,880.

Polymerization Processes

[00108] Polymerization processes may include solution, gas phase, slurry phase and a high pressure process or a combination thereof. In illustrative embodiments, a gas phase or slurry phase polymerization of one or more olefins at least one of which is ethylene or propylene is provided. Optionally, the reactor is a gas phase fluidized bed polymerization reactor.

[00109] The catalyst compositions or supported catalyst compositions as hereinbefore described are suitable for use in any prepolymerization and/or polymerization process over a wide range of temperatures and pressures. The temperatures may be in the range of from -60°C to about 280°C, from 50°C to about 200°C; from 60°C to 120°C from 70°C to 100°C or from 80°C to 95°C.

[00110] The present process may be directed toward a solution, high pressure, slurry or gas phase polymerization process of one or more olefin monomers having from 2 to 30 carbon atoms, preferably 2 to 12 carbon atoms, and more preferably 2 to 8 carbon atoms. The process is particularly well suited to the polymerization of two or more olefins or comonomers such as ethylene, propylene, 1-butene, 1-pentene, 4-methyl-1-pentene, 1-hexene, 1-octene 1-decene or the like.

[00111] Other olefins useful in the present process include ethylenically unsaturated monomers, diolefins having 4 to 18 carbon atoms, conjugated or nonconjugated dienes, polyenes, vinyl monomers and cyclic olefins. Useful monomers may include, but are not limited to, norbornene, norbornadiene, isobutylene, isoprene, vinylbenzocyclobutane, styrenes, alkyl substituted styrene, ethylidene norbornene, dicyclopentadiene and cyclopentene. In an illustrative embodiment of the present process, 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. In another embodiment of the present process, ethylene or propylene is polymerized with at least two different comonomers, optionally one of which may be a diene, to form a terpolymer.

[00112] The present process may be directed to a polymerization process, particularly a gas phase or slurry phase process, for polymerizing propylene alone or with one or more other monomers including ethylene, and/or other olefins having from 4 to 12 carbon atoms. The polymerization process may comprise contacting ethylene and optionally an alpha-olefin with one or more of the catalyst compositions or supported catalyst compositions as hereinbefore described in a reactor under polymerization conditions to produce the ethylene polymer or copolymer.

[00113] Suitable gas phase polymerization processes are described in, for example, U.S. Pat. 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, 5,668,228, 5,627,242, 5,665,818, and 5,677,375, and European publications EP-A-0 794 200, EP-A-0 802 202, EP-A2 0 891 990, and EP-B-634 421.

[00114] 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°C to about 120°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 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 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.

[00115] A preferred polymerization process 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. Pat. No. 3,248,179. Other slurry processes include those employing a loop reactor and those utilizing a plurality of 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. Pat. No. 4,613,484. Examples of solution processes are described in U.S. Pat. Nos. 4,271,060, 5,001,205, 5,236,998 and 5,589,555.

EXAMPLES

[00116] It is to be understood that while the present disclosure has been described in conjunction with the specific embodiments thereof, the foregoing description is intended to illustrate and not limit the scope of the disclosure. Other aspects, advantages and modifications will be apparent to those skilled in the art to which the disclosure pertains. Therefore, the following examples are put forth so as to provide those skilled in the art with a complete disclosure and description of how to make and use the disclosed compositions, and are not intended to limit the scope of the disclosure.

[00117] **General:** All reagents were purchased from commercial vendors and used as received unless otherwise noted. Solvents were sparged with N₂ and dried over 3 Å molecular

sieves. Analytical thin-layer chromatography (TLC) was performed on Selecto Plates (200 μ m) precoated with a fluorescent indicator. Visualization was effected using ultraviolet light (254 nm). Flash column chromatography was carried out with Sigma Aldrich Silica gel 60 Å (70 – 230 Mesh) using solvent systems specified. NMR spectra were recorded on a Bruker 400 or 500 NMR with chemical shifts referenced to residual solvent peaks.

[00118] The following examples are depicted in Figures 2 to 6.

[00119] **3,3''-((propane-1,3-diylbis(azanediyl))bis(methylene))bis([1,1'-biphenyl]-2-ol)**

(1): To phenyl phenol carboxaldehyde (3 g, 15.1 mmol) in 10 mL of methanol was added diaminopropane (0.63 mL, 7.5 mmol). After 5 minutes, sodium borohydride (2.3 g, 60.5 mmol) was added. The solution was poured over water and extracted with 3 portions of methylene chloride. The combined organic layers were dried (MgSO₄), filtered, and concentrated under reduced pressure giving the product as a yellow oil: ¹H NMR (400 MHz, CDCl₃, δ): 1.71 (m, 2 H), 2.70 (t, *J* = 9.0 Hz, 4 H), 3.98 (s, 4 H), 6.89 (m, 4 H), 7.31 (m, 4 H), 7.47 (m, 4 H), 7.65 (m, 4 H).

[00120] **3,3''-((propane-1,3-diylbismethylazanediyl))bis(methylene))bis([1,1'-biphenyl]-2-ol)**

(2): Amine (1) (526 mg, 1.19 mmol) was dissolved in acetonitrile (20 mL) and acetic acid (3 mL). Formaldehyde (1 mL, 37% in water) was added and the reaction stirred for 20 minutes. Sodium borohydride (200 mg, 5.2 mmol) was then added (CAUTION: H₂ evolves) and the mixture allowed to stir at ambient temperature overnight. It was then quenched with 2 N sodium hydroxide and extracted with 3 portions of methylene chloride. The combined organic layers were dried (MgSO₄), filtered, and concentrated under reduced pressure giving a crude oil that was purified by column chromatography (ethyl acetate/isohehexane 50:50): ¹H NMR (400 MHz, CDCl₃, δ): 1.86 (m, 2 H), 2.30 (s, 6 H), 5.55 (t, *J* = 7.6 Hz, 4 H), 3.76 (s, 4 H), 6.86 (t, *J* = 7.6 Hz, 2 H), 6.96 (m, 2 H), 7.31 (m, 4 H), 7.34 (t, *J* = 8.0 Hz, 4 H), 7.62 (m, 4 H).

[00121] **3,3''-((ethane-1,2-diylbismethylazanediyl)bismethylene))bis([1,1'-biphenyl]-2-ol)**

(3): Phenyl phenol (2.0 g, 4.4 mmol), dimethylethylenediamine (0.42 mL, 4.4 mmol), and paraformaldehyde (350 mg, 13.2 mmol) were dissolved in 40 mL of ethanol and heated at reflux for over 48 hours. The reaction was cooled and concentrated under reduced pressure and the resulting crude oil purified by passage over a silica gel plug (5% isopropanol/methylene chloride): ¹H NMR (400 MHz, CDCl₃, δ): 2.27 (m, 6 H), 2.59 (m, 4 H), 3.56 (m, 4 H), 6.85 (m, 2 H), 7.17 (m, 2 H), 7.42 (m, 8 H), 7.64 (m, 4 H).

[00122] **3-bromo-2-hydroxy-5-methylbenzaldehyde (4):** Prepared from bromocresol (10 g, 53.4 mmol) following the procedure of Hansen and Skattebol (Organic Syntheses **2005**, 82, 64-68). ¹H NMR (400 MHz, CDCl₃, δ): 2.34 (s, 3 H), 7.32 (s, 1 H), 7.61 (s, 1 H), 9.81 (s, 1 H).

[00123] **6,6'-((propane-1,3-diylbisazanediy)l)bismethylene)bis(2-bromo-4-methylphenol) (5):** Diaminopropane (1.0 mL, 11.3 mmol) was added to aldehyde (4) (5 g, 23.2 mmol) dissolved in 100 mL of MeOH/THF (1:1). Sodium borohydride (1.76 g, 46.4 mmol) was added slowly and a precipitate formed. The reaction was poured over water and the solid collected by filtration giving a yellow powder in 95% yield: ^1H NMR (400 MHz, DMSO- d_6 , δ): 1.60 (m, 2 H), 2.10 (s, 6 H), 2.50 (t, $J = 7.2$ Hz, 4 H), 3.79 (s, 4 H), 6.77 (s, 2 H), 7.12 (s, 2 H).

[00124] **6,6'-((propane-1,3-diylbismethylazanediy)l)bismethylene)bis(2-bromo-4-methylphenol) (6):** Diamine (5) (5.18 g, 10.9 mmol) was dissolved in acetonitrile (180 mL) and acetic acid (28 mL). Formaldehyde (8.5 mL, 37% aqueous solution) was added and the solution changed from yellow to colorless over 20 minutes. Sodium borohydride (1.8 g, 48 mmol) was added and the reaction stirred at ambient temperature overnight. Volatiles were then removed under reduced pressure and 2N sodium hydroxide was added. The aqueous solution was extracted with 3 portions of methylene chloride which was washed with water and brine, then dried, filtered, and concentrated to give the crude product as a pale brown oil in 67% yield: ^1H NMR (400 MHz, C_6D_6 , δ): 1.20 (qn, $J = 7.6$ Hz, 2 H), 1.67 (s, 6 H), 1.87 (t, $J = 7.6$ Hz, 4 H), 1.99 (s, 6 H), 3.08 (s, 4 H), 6.43 (d, $J = 1.2$ Hz, 2 H), 7.25 (d, $J = 1.6$ Hz, 2 H).

[00125] **3,3'-((propane-1,3-diylbismethylazanediy)l)bismethylene) bis(2',5-dimethyl-[1,1'-biphenyl]-2-ol) (7):** Dibromo compound (6) (1.0 g, 2.0 mmol), *ortho*-tolylboronic acid (600 mg, 4.4 mmol) and $\text{Pd}(\text{PPh}_3)_4$ (23 mg, 0.02 mmol) were dissolved in toluene (50 mL). Potassium carbonate (1.06 g, 9.9 mmol) in 10 mL of water was added and the mixture heated at reflux overnight. Upon cooling, water and ethyl acetate were added and the layers separated. The aqueous layer was extracted with addition portions of ethyl acetate. Combined organic layers were washed with brine, dried, filtered (MgSO_4), and concentrated. The crude tan oil was purified with silica gel chromatography, eluting with 10% acetone/isohexane: ^1H NMR (500 MHz, CDCl_3 , δ): 1.79 (m, 2 H), 2.21 (s, 6 H), 2.26 (s, 6 H), 2.28 (s, 6 H), 2.48 (t, $J = 8.5$ Hz, 4 H), 3.68 (br s, 4 H), 6.78 (s, 2 H), 6.89 (s, 2 H), 7.25 (m, 8 H); ^{13}C NMR (125 MHz, CDCl_3 , δ): 20.3 (2 C), 20.7 (2 C), 25.0, 41.4 (2 C), 55.1 (2 C), 61.8 (2 C), 121.6 (2 C), 125.7 (2 C), 127.4 (2 C), 127.8 (2 C), 128.5 (2 C), 129.3 (2 C), 129.9 (2 C), 130.2 (2 C), 130.8 (2 C), 136.9 (2 C), 138.9 (2 C), 152.8 (2 C); IR (cm^{-1}): 3454, 2953, 2919, 2849, 2809, 1608, 1461, 1239, 863.

[00126] **3,3'-((1,4-diazepane-1,4-diyl)bis(methylene))bis([1,1'-biphenyl]-2-ol) (8):** Phenylphenol (5.0 g, 29.3 mmol), homopiperazine (1.49 g, 14.6 mmol), and formaldehyde (2.41 mL, 37% aqueous solution) were combined in methanol and refluxed overnight. The white precipitate that was formed was isolated by filtration: ^1H NMR (500 MHz, CDCl_3 , δ): 1.70 (m, 2 H), 2.60 (s, 4 H), 2.63 (m, 4 H), 3.62 (s, 4 H), 6.63 (t, $J = 7.5$ Hz, 2 H), 6.74 (m, 2 H), 7.04 (m, 2 H).

H), 7.10 (m, 2 H), 7.23 (m, 4 H), 7.39 (m, 4 H); ^{13}C NMR (125 MHz, CDCl_3 , δ): 26.5, 53.6, 53.7, 54.4 (2 C), 62.2 (2 C), 119.3 (2 C), 122.3 (2 C), 127.0 - 130.3 (16 C), 138.7 (2 C), 155.3 (2 C).

[00127] Zr complex (9): The above ligand (8) (85 mg) was dissolved in 5 mL of toluene. ZrBn_2Cl_2 (72 mg) in 5 mL of toluene was added to the ligand solution and the reaction heated at 85 °C for 2 h. A precipitate formed which was collected and washed with pentane.

[00128] **3,3'-(piperazine-1,4-diylbis(methylene))bis([1,1'-biphenyl]-2-ol) (10):**

^1H NMR (500 MHz, $\text{tol}-d_6$, 361 K, δ): 2.02 (br s, 8 H), 3.24 (s, 4 H), 6.75 (m, 4 H), 7.15 (m, 2 H), 7.29 (m, 6 H), 7.74 (m, 4 H); ^{13}C NMR (125 MHz, $\text{tol}-d_6$, 361 K, δ): 51.9 (4 C), 61.2 (2 C), 119.2 (2 C), 126.6 (2 C), 127.8 (4 C), 129.5 (2 C), 129.7 (4 C), 130.2 (2 C), 139.1 (2 C), 155.4 (2 C); IR (cm^{-1}): 3531, 3419, 3056, 2948, 2879, 2826, 1592, 1458, 1430, 1270, 977, 909, 828.

Zr complex (11): The above ligand (10) (74 mg) was dissolved in 5 mL of toluene. ZrBn_2Cl_2 (54 mg) in 5 mL of toluene was added to the ligand solution and the reaction heated at 85 °C for 2 h. A precipitate formed which was collected and washed with pentane.

[00129] **General procedure for supporting catalysts:** The zirconium complex, typically between 15 to 30 mg, was dissolved in toluene and a solution of MAO (Albemarle, 30 wt. %). Silica gel (757 previously dehydrated at 600°C) was added and the slurry stirred until completely mixed, approx. 5 min. Toluene was then removed under vacuum to yield the supported catalyst

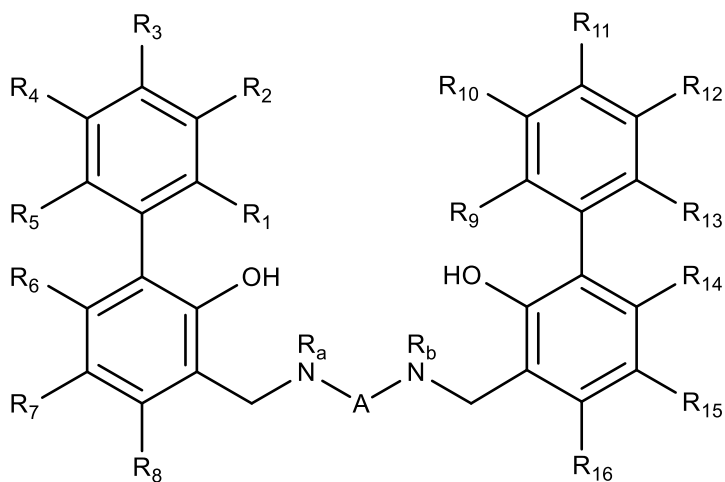
[00130] For the sake of brevity, only certain ranges are explicitly disclosed herein. However, ranges from any lower limit may be combined with any upper limit to recite a range not explicitly recited, as well as, ranges from any lower limit may be combined with any other lower limit to recite a range not explicitly recited, in the same way, ranges from any upper limit may be combined with any other upper limit to recite a range not explicitly recited.

[00131] All documents cited are herein fully incorporated by reference for all jurisdictions in which such incorporation is permitted and to the extent such disclosure is consistent with the description of the present disclosure.

CLAIMS

What is claimed is:

1. A bis(aminophenylphenol) ligand of formula (I):



(I)

wherein each of R₁, R₂, R₃, R₄, R₅, R₆, R₇, R₈, R₉, R₁₀, R₁₁, R₁₂, R₁₃, R₁₄, R₁₅ and R₁₆ is independently selected from the group consisting of hydride, halide, optionally substituted hydrocarbyl, heteroatom-containing optionally substituted hydrocarbyl, alkoxy, aryloxy, silyl, boryl, dialkyl amino, alkylthio, arylthio and seleno, with the proviso that none of R₁, R₂, R₃, R₄, R₅, R₉, R₁₀, R₁₁, R₁₂ and R₁₃ comprise fluorine; optionally two or more R groups can combine together into ring structures with such ring structures having from 3 to 100 non-hydrogen atoms in the ring; A is a bridging group having from one to 50 non-hydrogen atoms; R_a and R_b are joined to form a bridging group, E, having from one to 50 non-hydrogen atoms; and

wherein R_a and R_b are joined to form a bridging group, E, wherein said bridging group is selected from the group consisting of optionally substituted divalent hydrocarbyl and divalent heteroatom containing hydrocarbyl; or

wherein, R_a and R_b are joined to form a bridging group, E, wherein said bridging group is selected from the group consisting of optionally substituted divalent alkyl, optionally substituted divalent cycloalkyl, alkenyl, alkynyl, heteroalkyl, heterocycloalkyl, heteroalkenyl, heteroalkynyl, carbocycle, heterocarbocycle, aryl, heteroaryl and silyl; or

wherein R_a and R_b are joined to form a bridging group represented by the general formula—(QR¹⁸_{2-z''})_{z'}—wherein each Q is either carbon or silicon and each R¹⁸ may be the same or different from the others such that each R¹⁸ is selected from the group consisting of hydride and optionally substituted hydrocarbyl and heteroatom containing hydrocarbyl, and optionally two or more R¹⁸ groups may be joined into a ring structure having from 3 to 50 atoms in the ring structure not counting hydrogen atoms; z' is an integer from 1 to 10; and z'' is 0, 1 or 2.

2. A ligand according to claim 1, wherein each of R₁, R₂, R₃, R₄, R₅, R₆, R₇, R₈, R₉, R₁₀, R₁₁, R₁₂, R₁₃, R₁₄, R₁₅ and R₁₆ is independently selected from the group consisting of hydride, halide, optionally substituted alkyl, optionally substituted cycloalkyl, heteroalkyl, heterocycloalkyl, aryl, heteroaryl, alkoxy, aryloxy, silyl, dialkylamino, alkylthio, and arylthio; or

wherein each of R₁, R₂, R₃, R₄, R₅, R₆, R₇, R₈, R₉, R₁₀, R₁₁, R₁₂, R₁₃, R₁₄, R₁₅ and R₁₆ is independently selected from the group consisting of hydride, halide, optionally substituted alkyl, optionally substituted cycloalkyl, heteroalkyl, heterocycloalkyl, aryl, heteroaryl, alkoxy, and aryloxy; or

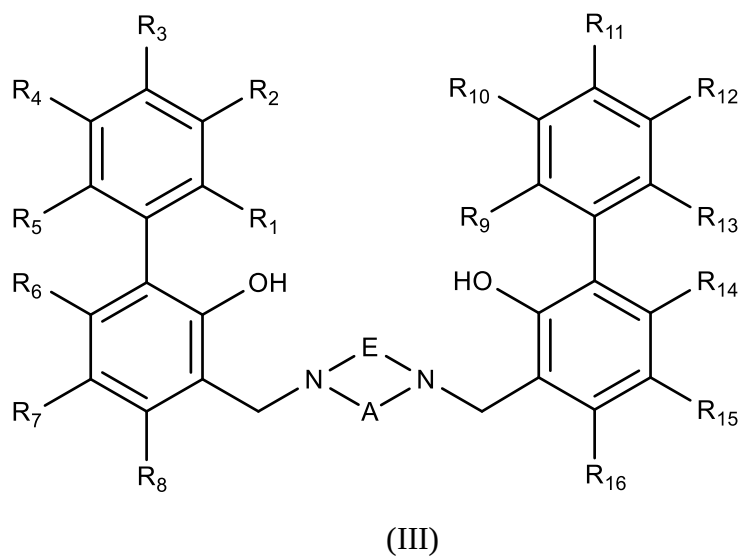
wherein the bridging group A is selected from the group consisting of optionally substituted divalent hydrocarbyl and divalent heteroatom containing hydrocarbyl; or

wherein the bridging group A is selected from the group consisting of optionally substituted divalent alkyl, optionally substituted cycloalkyl alkenyl, alkynyl, heteroalkyl, heterocycloalkyl, heteroalkenyl, heteroalkynyl, carbocycle, heterocarbocycle, aryl, heteroaryl and silyl; or

wherein the bridging group A is represented by the general formula—(QR¹⁷_{2-z''})_{z'}—wherein each Q is either carbon or silicon and each R¹⁷ may be the same or different from the others such that each R¹⁷ is selected from the group consisting of hydride and optionally substituted hydrocarbyl and heteroatom containing hydrocarbyl, and optionally two or more R¹⁷ groups may be joined into a ring structure having from 3 to 50 atoms in the ring structure not counting hydrogen atoms; z' is an integer from 1 to 10; and z'' is 0, 1 or 2; or

wherein R_a and R_b are independently selected from hydride or optionally substituted alkyl or cycloalkyl.

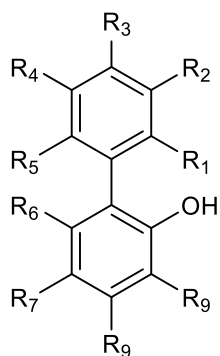
3. A ligand according to claim 1 having formula (III):



wherein each of R₁, R₂, R₃, R₄, R₅, R₆, R₇, R₈, R₉, R₁₀, R₁₁, R₁₂, R₁₃, R₁₄, R₁₅ and R₁₆ is as defined in claim 1 and A and E are independently optionally substituted divalent alkyl or cycloalkyl; or

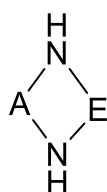
wherein the bridging groups A and E are the same or different divalent alkyl groups or cycloalkyl groups, containing from 1 to 10 carbon atoms.

4. A method of preparing a ligand according to any one of claims 1 to 3, wherein the method comprises at least one step of reductive amination or Mannich aminoalkylation and the step of treating an arylphenol of formula (VI):



(VI)

wherein R_1 to R_7 and R_9 , are as defined in claim 1, with a heterocycle of formula (VII):



(VII)

wherein A and E are as defined in claim 1,

in the presence of formaldehyde, or a source of formaldehyde, to yield the bis(aminophenylphenol) ligand of formula (I) as defined in claim 1 or formula (III) as defined in claim 3.

5. A method according to claim 4 wherein each of R₁, R₂, R₃, R₄, R₅, R₆, R₇, R₈, R₉, R₁₀, R₁₁, R₁₂, R₁₃, R₁₄, R₁₅ and R₁₆ is independently selected from the group consisting of hydride, halide, optionally substituted alkyl, optionally substituted cycloalkyl, heteroalkyl, heterocycloalkyl, aryl, heteroaryl, alkoxyl, aryloxy, silyl, dialkylamino, alkylthio, and arylthio; or

wherein each of R₁, R₂, R₃, R₄, R₅, R₆, R₇, R₈, R₉, R₁₀, R₁₁, R₁₂, R₁₃, R₁₄, R₁₅ and R₁₆ is independently selected from the group consisting of hydride, halide, optionally substituted alkyl, optionally substituted cycloalkyl, heteroalkyl, heterocycloalkyl, aryl, heteroaryl, alkoxyl, and aryloxy; or

wherein the bridging group A is selected from the group consisting of optionally substituted divalent hydrocarbyl and divalent heteroatom containing hydrocarbyl; or

wherein the bridging group A is selected from the group consisting of optionally substituted divalent alkyl, optionally substituted divalent cycloalkyl, alkenyl, alkynyl, heteroalkyl, heterocycloalkyl, heteroalkenyl, heteroalkynyl, carbocycle, heterocarbocycle, aryl, heteroaryl and silyl; or

wherein the bridging group A is represented by the general formula—(QR¹⁷_{2-z''})_{z'}—wherein each Q is either carbon or silicon and each R¹⁷ may be the same or different from the others such that each R¹⁷ is selected from the group consisting of hydride and optionally substituted hydrocarbyl and heteroatom containing hydrocarbyl, and optionally two or more R¹⁷ groups may be joined into a ring structure having

from 3 to 50 atoms in the ring structure not counting hydrogen atoms; z' is an integer from 1 to 10; and z'' is 0, 1 or 2; or

wherein R_a and R_b is independently selected from hydride or optionally substituted alkyl or cycloalkyl; or

wherein R_a and R_b are joined to form a bridging group, wherein said bridging group is selected from the group consisting of optionally substituted divalent hydrocarbyl and divalent heteroatom containing hydrocarbyl; or

wherein R_a and R_b are joined to form a bridging group, wherein said bridging group is selected from the group consisting of optionally substituted divalent alkyl, optionally substituted divalent cycloalkyl, alkenyl, alkynyl, heteroalkyl, heterocycloalkyl, heteroalkenyl, heteroalkynyl, carbocycle, heterocarbocycle, aryl, heteroaryl and silyl; or

wherein R_a and R_b are joined to form a bridging group represented by the general formula— $(QR^{18}_{2-z'})_{z'}$ —wherein each Q is either carbon or silicon and each R^{18} may be the same or different from the others such that each R^{18} is selected from the group consisting of hydride and optionally substituted hydrocarbyl and heteroatom containing hydrocarbyl, and optionally two or more R^{18} groups may be joined into a ring structure having from 3 to 50 atoms in the ring structure not counting hydrogen atoms; z' is an integer from 1 to 10; and z'' is 0, 1 or 2.

6. A transition metal compound comprising a ligand according to any one of claims 1 to 3, wherein the transition metal compound comprises one or more titanium, zirconium or hafnium atoms.

7. A catalyst composition comprising one or more transition metal compounds according to claim 6 and one or more activators; or
a supported catalyst composition comprising one or more transition metal compounds according to claim 6, one or more activators and one or more support materials;
wherein the activator comprises methyalumoxane; or
wherein the supported catalyst composition comprises one or more other transition metal compounds.

8. A process for polymerizing olefins, the process comprising:
contacting olefins with one or more catalyst compositions or supported catalyst compositions according to claim 7 in a reactor under polymerization conditions to produce an olefin polymer or copolymer.