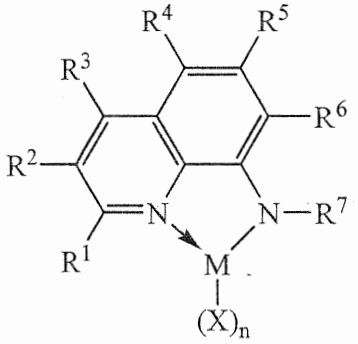
CLAIMS

What is claimed is:

1. A process for polymerizing an olefin monomer, the process comprising a step of contacting together a catalytic amount of a catalyst system, said catalyst system having at least one olefin polymerization catalyst comprising a mixture or reaction product of ingredients (a) and (b), wherein ingredient (a) comprises a metal-ligand complex and ingredient (b) comprises an activating co-catalyst; an olefin monomer as ingredient (c); and a chain shuttling agent as ingredient (d);

the ingredient (a) being one or more metal-ligand complexes (also referred to herein as precatalysts) of formula (I):



(I)

wherein:

M is a metal of Group 4 of the Periodic Table of the Elements, the metal being in a formal oxidation state of +3 or +4;

n is an integer of from 1 to 5;

Each X independently is a monodentate ligand that is neutral, monoanionic, or dianionic; or two X are taken together to form a bidentate ligand that is neutral, monoanionic, or dianionic;

X and n are chosen in such a way that the metal-ligand complex of formula (I) is, in aggregate, neutral;

Each of R^1 to R^6 independently is a hydrogen atom, $(C_1\text{-}C_{40})$hydrocarbyl, $(C_1\text{-}C_{40})$heterohydrocarbyl, $(C_1\text{-}C_{40})$hydrocarbyl-O-, or halogen atom;

R^7 independently is a $(C_1\text{-}C_{40})$hydrocarbyl or $(C_1\text{-}C_{40})$heterohydrocarbyl;

Or one X, when a monodentate ligand, is taken together with any one of R^1 to R^7 in such a way so that the metal-ligand complex of formula (I) contains a tridentate ligand;

Each of the aforementioned hydrocarbyl and heterohydrocarbyl independently is unsubstituted or substituted with one or more substituents R^S; and

Each R^S independently is a halogen atom, polyfluoro, perfluoro, unsubstituted $(C_1\text{-}C_{18})$alkyl, F_3C-, FCH_2O-, F_2HCO-, F_3CO-, R_3Si-, RO-, RS-, RS(O)-, $RS(O)_2$-, R_2P-, R_2N-, $R_2C{=}N$-, NC-, RC(O)O-, ROC(O)-, RC(O)N(R)-, or $R_2NC(O)$-, wherein each R independently is an unsubstituted $(C_1\text{-}C_{18})$alkyl; and

the ingredient (b) being one or more activating co-catalysts, or a reaction product thereof, wherein the ratio of total number of moles of the one or more metal-ligand complexes of formula (I) to total number of moles of the one or more activating co-catalysts is from 1:10,000 to 100:1;

wherein the contacting step is performed under olefin polymerizing conditions and prepares a polyolefin.

2. The process as in claim 1, wherein the metal-ligand complex of formula (I) is characterized by any one or more of limitations (a) to (l):

(a) M is hafnium;

(b) n is 3 and each X is a monodentate ligand that is a monoanionic ligand;

(c) at least R^1 is $(C_1\text{-}C_{40})$hydrocarbyl;

(d) R^7 is a substituted $(C_6\text{-}C_{40})$aryl;

(e) at least R^3 is $(C_1\text{-}C_{40})$hydrocarbyl;

(f) the catalyst is characterized by a catalyst efficiency of at least 130,000 grams of the polyolefin per gram of metal (M) of the metal-ligand complex of formula (I) when measured at a reaction mixture temperature of 120 degrees Celsius as in Example F1 or 135 degrees Celsius as in Example E;

3. The process as in claim 1, wherein the polyolefin prepared using the metal-ligand complex of formula (I) is characterized by any one or more of limitations (g) to (l):

(g) the polyolefin is a poly(ethylene alpha-olefin) copolymer characterized with differential scanning calorimetry by a crystallization transition temperature (i.e., T_c) of 60 °C or higher; heat flow versus temperature cooling and heating curves independently exhibiting single peaks for both crystallization and melting transitions, respectively; and either (i) a full width at half maximum peak height in degrees Celsius ($W_{½(DSC)}$) corresponding to a crystallization transition from the DSC cooling curve of less than 5.0 degrees Celsius or (ii) a multiplication product of T_c times $W_{½(DSC)}$ that is less than 500 degrees Celsius squared;

(h) the polyolefin is a poly(ethylene alpha-olefin) copolymer characterized by a polydispersity index of less than 3.0;

(i) the polyolefin is a poly(ethylene alpha-olefin) copolymer characterized with proton nuclear magnetic resonance spectroscopy by a mole percent of vinyl groups, expressed as $-CH=CH_2$ groups per 1000 carbon atoms of the polyolefin, of less than 0.10 mole percent;

(j) the polyolefin is a poly(ethylene alpha-olefin) copolymer characterized by a weight average molecular weight of at least 500,000 grams per mole as determined by gel permeation chromatography;

(k) the polyolefin is a poly(ethylene alpha-olefin) copolymer characterized by a number average molecular weight of at least 170,000 grams per mole as determined by gel permeation chromatography; and

(l) the process is performed at a reaction temperature of at least 140 degrees Celsius and less than 300 degrees Celsius.

4. The process as in claims 2 and 3, the process being characterized by at least each of limitations (a) to (c) and limitation (d); or

at least each of limitations (a) to (c) and limitation (e) and, optionally, limitation (d); or

at least each of limitations (a) to (c) and limitation (f) and, optionally, limitation (d) or (e), or limitations (d) and (e); or

at least each of limitations (a) to (c) and limitation (g) and, optionally, limitation (d), (e), or (f) or limitations (d), (e) and (f); or

at least each of limitations (a) to (c) and limitation (h) and, optionally, limitation (d), (e), (f), or (g) or limitations (d), (e), (f) and (g); or

at least each of limitations (a) to (c) and limitation (i) and, optionally, limitation (d), (e), (f), (g), or (h) or limitations (d), (e), (f), (g) and (h); or

at least each of limitations (a) to (c) and limitation (j) and, optionally, limitation (d), (e), (f), (g), (h), or (i) or limitations (d), (e), (f), (g), (h) and (i); or

at least each of limitations (a) to (c) and limitation (k) and, optionally, limitation (d), (e), (f), (g), (h), (i), or (j) or limitations (d), (e), (f), (g), (h), (i) and (j); or

at least each of limitations (a) to (c) and limitation (k) and, optionally, limitation (d), (e), (f), (g), (h), (i), (j), or (k) or limitations (d), (e), (f), (g), (h), (i), (j) and (k); or

at least each of limitations (a) to (c) and limitation (k) and, optionally, limitation (d), (e), (f), (g), (h), (i), (j), (k), or (l) or limitations (d), (e), (f), (g), (h), (i), (j), (k) and (l).

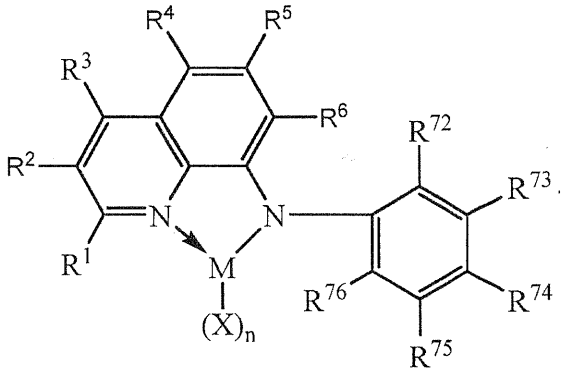
5. The process as in any one of claims 2 to 4, the polyolefin being the poly(ethylene alpha-olefin) copolymer, the poly(ethylene alpha-olefin) copolymer being characterized by at least a combination comprising a polydispersity index of less than 3.0; single peaks observed in both the DSC heating and cooling curves; and $W_{½(DSC)}$ less than 5.0 degrees Celsius; or

the polyolefin being the poly(ethylene alpha-olefin) copolymer, the poly(ethylene alpha-olefin) copolymer being characterized by at least a combination comprising a polydispersity index of less than 2.5; $W_{½(DSC)}$ less than 4.0 degrees Celsius; and the mole percent vinyl groups is less than 0.03 mole percent; or

the polyolefin being the poly(ethylene alpha-olefin) copolymer, the poly(ethylene alpha-olefin) copolymer being characterized by at least a combination comprising a polydispersity index of less than 3.0; single peaks observed in both the DSC heating and cooling curves; and $T_c*W_{½(DSC)}$ less than 500 degrees Celsius squared; or

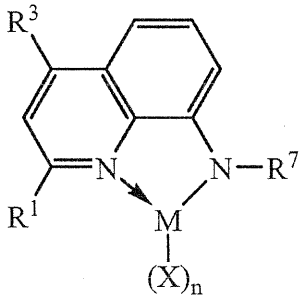
the polyolefin being the poly(ethylene alpha-olefin) copolymer, the poly(ethylene alpha-olefin) copolymer being characterized by at least a combination comprising a polydispersity index of less than 2.5; $T_c*W_{½(DSC)}$ less than 400 degrees Celsius squared; and the mole percent vinyl groups is less than 0.03 mole percent.

6. The process as in any one of claims 1 to 5, wherein the metal-ligand complex of formula (I) is a metal-ligand complex of formula (Ip), (Ia), (Ia-1), (Ia-1.1), or (Ia-2):



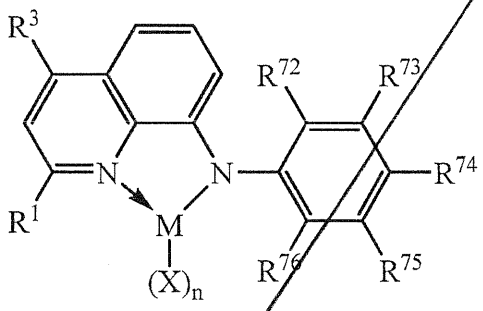
(Ip)

wherein at least one of R^{72} and R^{76} independently is a $(C_1\text{-}C_{40})$alkyl and each of the remainder of R^{72} to R^{76} independently is a hydrogen atom or R^S;



(Ia)

;

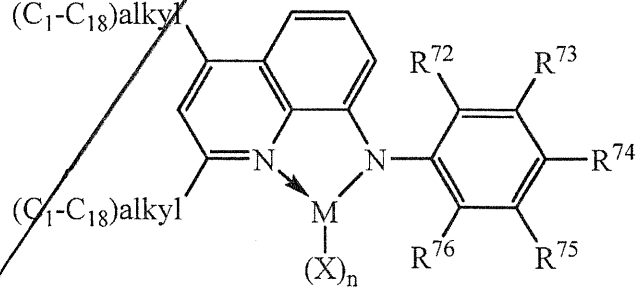


(Ia-1)

,

Wherein in formula (Ia-1) each of R^{72} to R^{76} independently is a hydrogen atom or R^S, wherein R^S is as defined previously; or

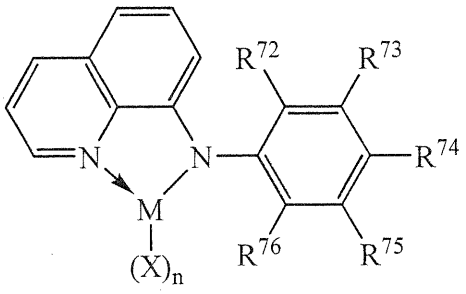
$(C_1\text{-}C_{18})$alkyl



(Ia-1.1)

$(C_1\text{-}C_{18})$alkyl

; or

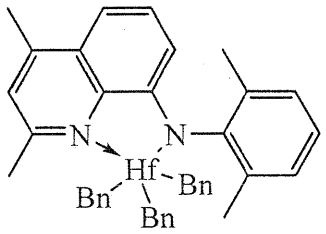


(Ia-1.2)

7. The process as in claim 6, wherein at least one of R^{72} and R^{76} independently is a $(C_1\text{-}C_{40})$alkyl.

8. The process as in any one of claims 1 to 7, wherein R^1 is $(C_1\text{-}C_{40})$hydrocarbyl, $(C_1\text{-}C_{40})$heterohydrocarbyl, $(C_1\text{-}C_{40})$hydrocarbyl-O-, or halogen atom.

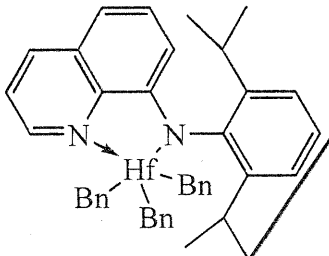
9. The process as in claim 6, wherein the metal-ligand complex of formula (Ia-1.1) is metal-ligand complex (8):



(8)

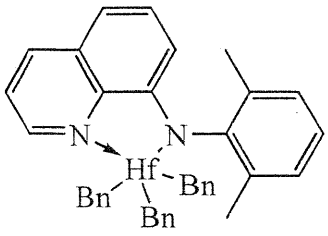
; and

wherein the metal-ligand complex of formula (Ia-1.2) is any one of metal-ligand complexes (5) to (7) and (10):



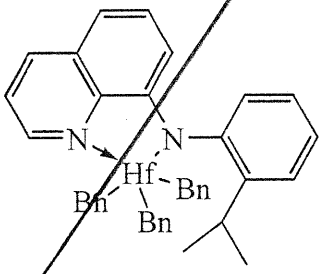
(5)

;



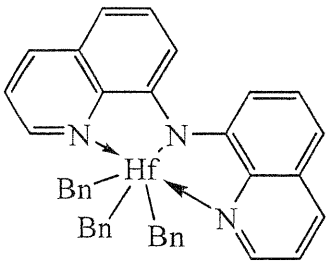
(6)

;



(7)

; and



(10)

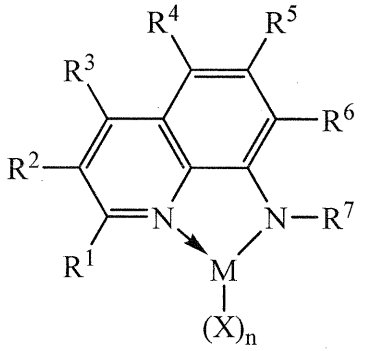
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CLAIMS

What is claimed is:

1. A process for polymerizing an olefin monomer, the process comprising a step of contacting together a catalytic amount of a catalyst comprising a mixture or reaction product of ingredients (a) and (b), wherein ingredient (a) comprises a metal-ligand complex and ingredient (b) comprises an activating co-catalyst; and an olefin monomer as ingredient (c);

the component (a) being one or more metal-ligand complexes of formula (I):



(I)

wherein:

M is a metal of Group 4 of the Periodic Table of the Elements, the metal being in a formal oxidation state of +3 or +4;

n is an integer of from 1 to 5;

Each X independently is a monodentate ligand that is neutral, monoanionic, or dianionic; or two X are taken together to form a bidentate ligand that is neutral, monoanionic, or dianionic;

X and n are chosen in such a way that the metal-ligand complex of formula (I) is, in aggregate, neutral;

Each of R^1 to R^6 independently is a hydrogen atom, $(C_1\text{-}C_{40})$hydrocarbyl, $(C_1\text{-}C_{40})$heterohydrocarbyl, $(C_1\text{-}C_{40})$hydrocarbyl-O-, or halogen atom;

R^7 independently is a $(C_1\text{-}C_{40})$hydrocarbyl or $(C_1\text{-}C_{40})$heterohydrocarbyl;

Or one X, when a monodentate ligand, is taken together with any one of R^1 to R^7 in such a way so that the metal-ligand complex of formula (I) contains a tridentate ligand;

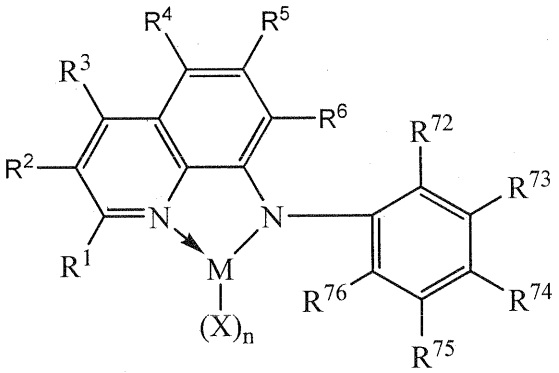
Each of the aforementioned hydrocarbyl and heterohydrocarbyl independently is unsubstituted or substituted with one or more substituents R^S; and

Each R^S independently is a halogen atom, polyfluoro, perfluoro, unsubstituted $(C_1$-$C_{18})$alkyl, F_3C-, FCH_2O-, F_2HCO-, F_3CO-, R_3Si-, RO-, RS-, RS(O)-, $RS(O)_2$-, R_2P-, R_2N-, R_2C=N-, NC-, RC(O)O-, ROC(O)-, RC(O)N(R)-, or $R_2NC(O)$-, wherein each R independently is an unsubstituted $(C_1$-$C_{18})$alkyl; and

the component (b) being one or more activating co-catalysts, or a reaction product thereof, wherein the ratio of total number of moles of the one or more metal-ligand complexes of formula (I) to total number of moles of the one or more activating co-catalysts is from 1:10,000 to 100:1;

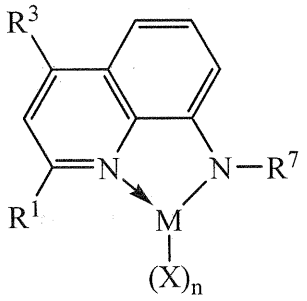
wherein the contacting step is performed under olefin polymerizing conditions and prepares a polyolefin, and

wherein the metal-ligand complex of formula (I) is a metal-ligand complex of formula (Ip), (Ia), (Ia-1), (Ia-1.1), or (Ia-1.2):



(Ip)

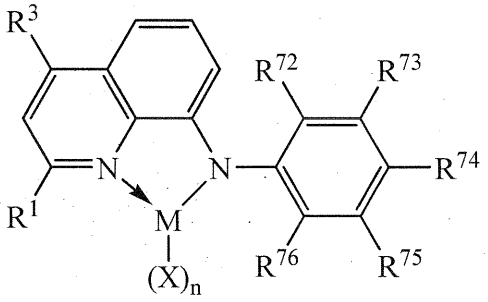
wherein at least one of R^{72} and R^{76} independently is a $(C_1$-$C_{40})$alkyl and each of the remainder of R^{72} to R^{76} independently is a hydrogen atom or R^S;



(Ia)

;

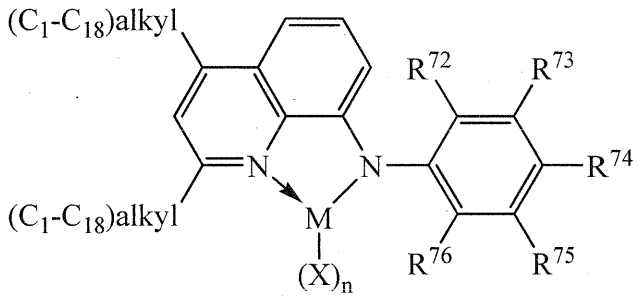
wherein in formula (Ia) each of R^1 and R^3 independently is a $(C_1$-$C_{40})$ hydrocarbyl or $(C_1$-$C_{40})$ heterohydrocarbyl;



(Ia-1)

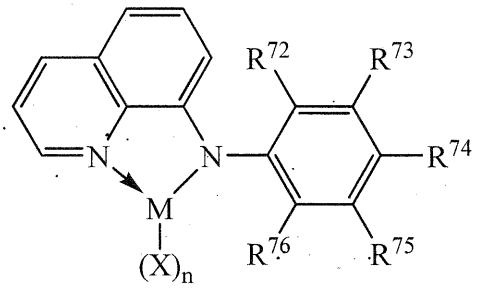
,

wherein in formula (Ia-1) each of R^{72} to R^{76} independently is a hydrogen atom, a $(C_1\text{-}C_{40})$ alkyl, or R^S, wherein R^S is as defined previously; and wherein in formula (Ia-1) each of R^1 and R^3 independently is a $(C_1\text{-}C_{40})$ hydrocarbyl or $(C_1\text{-}C_{40})$ heterohydrocarbyl; or



(Ia-1.1)

wherein in formula (Ia-1.1) each of R^{72} to R^{76} independently is a hydrogen atom, a $(C_1\text{-}C_{40})$ alkyl, or R^S, wherein R^S is as defined previously; or



(Ia-1.2)

wherein in formula (Ia-1.2) each of R^{72} to R^{76} independently is a hydrogen atom, a $(C_1\text{-}C_{40})$ alkyl, or R^S, wherein R^S is as defined previously.

2. The process as in claim 1, wherein the metal-ligand complex of formula (I) is characterizable by any one or more of limitations (a) to (l):

(a) M is hafnium;

(b) n is 3 and each X is a monodentate ligand that is a monoanionic ligand;

(c) at least R^1 is $(C_1\text{-}C_{40})$hydrocarbyl;

(d) R^7 is a substituted $(C_6\text{-}C_{40})$aryl;

(e) at least R^3 is $(C_1\text{-}C_{40})$hydrocarbyl;

(f) the catalyst is characterized by a catalyst efficiency of at least 130,000 grams of the polyolefin per gram of metal (M) of the metal-ligand complex of formula (I);

(g) the polyolefin is a poly(ethylene alpha-olefin) copolymer characterized by a differential scanning calorimetry crystallization transition temperature (T_c) of 60° C or higher; heat flow versus temperature cooling and heating curves independently exhibiting single peaks for both crystallization and melting transitions, respectively; and either (i) a full width at half maximum peak height in degrees Celsius ($W_{½(DSC)}$) corresponding to a crystallization transition from the DSC cooling curve of less than 5.0° C or (ii) a multiplication product of T_c*$W_{½(DSC)}$ that is less than 500° C squared;

(h) the polyolefin is a poly(ethylene alpha-olefin) copolymer characterized by a polydispersity index of less than 3.0;

(i) the polyolefin is a poly(ethylene alpha-olefin) copolymer characterized by a ^{1}H NMR spectroscopy by a mole percent of vinyl groups, expressed as -CH=CH_2 groups per 1000 carbon atoms of the polyolefin, of less than 0.10 mole percent;

(j) the polyolefin is a poly(ethylene alpha-olefin) copolymer characterized by a weight average molecular weight of at least 500,000 grams per mole as determined by gel permeation chromatography;

(k) the polyolefin is a poly(ethylene alpha-olefin) copolymer characterized by a number average molecular weight of at least 170,000 grams per mole as determined by gel permeation chromatography; and

(l) the process is performed at a reaction temperature of at least 140° C and less than 300 ° C .

3. The process as in claim 2, the process being characterized by at least each of limitations (a) to (c) and limitation (d); or

The process being characterized by at least each of limitations (a) to (c) and limitation (e) and, optionally, limitation (d); or

The process being characterized by at least each of limitations (a) to (c) and limitation (f) and, optionally, limitation (d) or (e), or limitations (d) and (e); or

The process being characterized by at least each of limitations (a) to (c) and limitation (g) and, optionally, limitation (d), (e), or (f) or limitations (d), (e) and (f); or

The process being characterized by at least each of limitations (a) to (c) and limitation (h) and, optionally, limitation (d), (e), (f), or (g) or limitations (d), (e), (f) and (g); or

The process being characterized by at least each of limitations (a) to (c) and limitation (i) and, optionally, limitation (d), (e), (f), (g), or (h) or limitations (d), (e), (f), (g) and (h); or

The process being characterized by at least each of limitations (a) to (c) and limitation (j) and, optionally, limitation (d), (e), (f), (g), (h), or (i) or limitations (d), (e), (f), (g), (h) and (i); or

The process being characterized by at least each of limitations (a) to (c) and limitation (k) and, optionally, limitation (d), (e), (f), (g), (h), (i), or (j) or limitations (d), (e), (f), (g), (h), (i) and (j); or

The process being characterized by at least each of limitations (a) to (c) and limitation (k) and, optionally, limitation (d), (e), (f), (g), (h), (i), (j), or (k) or limitations (d), (e), (f), (g), (h), (i), (j) and (k); or

The process being characterized by at least each of limitations (a) to (c) and limitation (k) and, optionally, limitation (d), (e), (f), (g), (h), (i), (j), (k), or (l) or limitations (d), (e), (f), (g), (h), (i), (j), (k) and (l).

4. The process as in claim 2 or 3, wherein the polyolefin is a poly(ethylene alpha-olefin) copolymer, the poly(ethylene alpha-olefin) copolymer being characterized by at least a combination comprising a polydispersity index of less than 3.0; single peaks observed in both the DSC heating and cooling curves; and $W_{½(DSC)}$ less than 5.0° C; or

wherein the polyolefin is a poly(ethylene alpha-olefin) copolymer, the poly(ethylene alpha-olefin) copolymer is characterized by at least a combination comprising a

polydispersity index of less than 2.5; $W_{½(DSC)}$ less than 4.0° C; and the mole percent vinyl groups is less than 0.03 mole percent; or

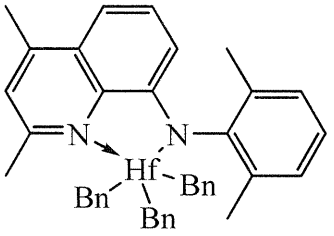
wherein the polyolefin is a poly(ethylene alpha-olefin) copolymer, the poly(ethylene alpha-olefin) copolymer is characterized by at least a combination comprising a polydispersity index of less than 3.0; single peaks observed in both the DSC heating and cooling curves; and $T_c*W_{½(DSC)}$ less than 500° C squared; or

wherein the polyolefin is a poly(ethylene alpha-olefin) copolymer, the poly(ethylene alpha-olefin) copolymer is characterized by at least a combination comprising a polydispersity index of less than 2.5; $T_c*W_{½(DSC)}$ less than 400° C squared; and the mole percent vinyl groups is less than 0.03 mole percent.

5. The process as in claim 4, wherein the catalyst is characterized by a catalyst efficiency of at least 200,000 grams of the polyolefin per gram of metal (M) of the metal-ligand complex of formula (I).

6. The process as in claim 1, wherein in the metal-ligand complex of formula (Ip) R^1 is $(C_1\text{-}C_{40})$hydrocarbyl, $(C_1\text{-}C_{40})$heterohydrocarbyl, $(C_1\text{-}C_{40})$hydrocarbyl-O-, or halogen atom.

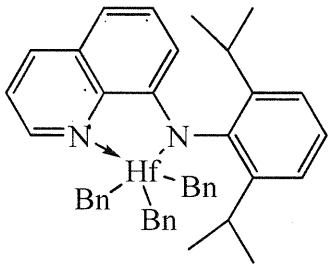
7. The process as in claim 1, wherein the metal-ligand complex is metal-ligand complex (8):



(8)

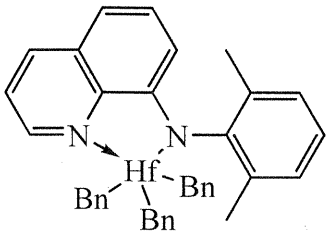
; or

any one of metal-ligand complexes (5) to (7) and (10):



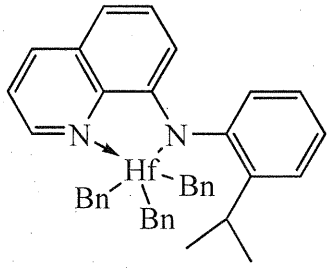
(5)

;

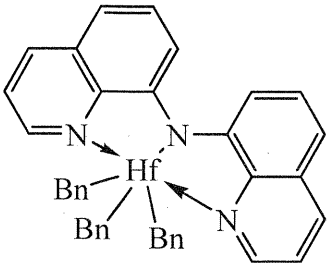


(6)

;



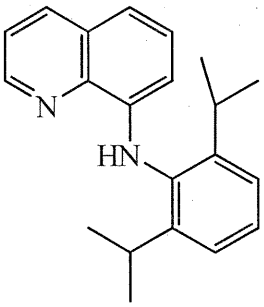
(7)



(10)

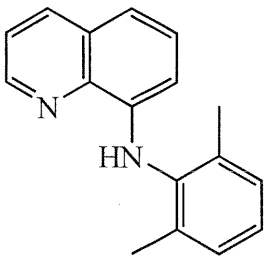
; and .

8. A ligand of any one of formulas (1) to (4):



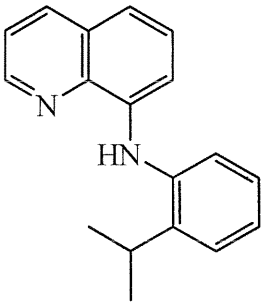
(1)

;



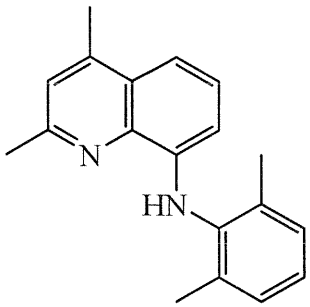
(2)

;



(3)

; and



(4)

;

or a Group 1 or 2 metal salt thereof.

9. A metal complex comprising the ligand of claim 8.

10. A catalyst comprising the metal complex of claim 9.