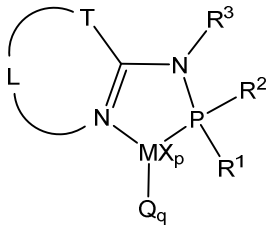
CLAIMS

What is claimed is:

1. A catalyst system comprising

   i) a heterocyclic 2-[(phosphinyl)aminyl]imine transition metal compound complex having Structure HCPAITMC 1



Structure HCPAITMC 1

   wherein

   T is oxygen or sulfur,

   R^1 and R^2 are each independently a C_1 to C_{20} organyl group consisting essentially of inert functional groups,

   R^3 is hydrogen or a C_1 to C_{20} organyl group,

   L is a C_1 to C_{20} organylene group consisting essentially of inert functional groups,

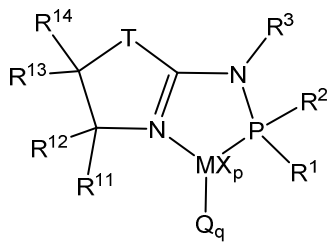
   MX_p represents a transition metal compound where M is chromium, X is a monoanion, and p is an integer from 1 to 6,

   Q is a neutral ligand, and

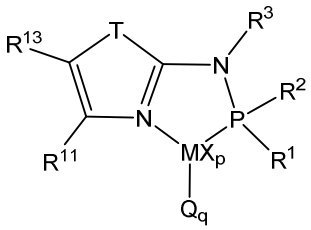
   q ranges from 0 to 6, and

   ii) an organoaluminum compound.

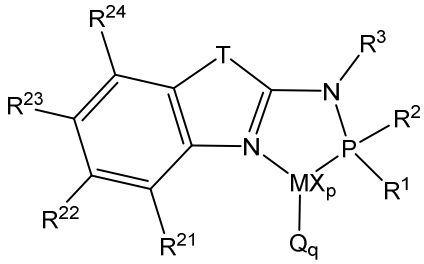
2. The catalyst system of claim 1, wherein the heterocyclic 2-[(phosphinyl)aminyl]imine transition metal compound complex has Structure HCPAITMC 2, Structure HCPAITMC 3, Structure HCPAITMC 4, Structure HCPAITMC 5, or Structure HCPAITMC 6



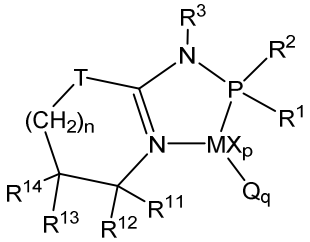
Structure HCPAITMC 2



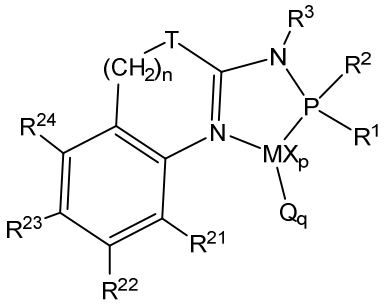
Structure HCPAITMC 3



Structure HCPAITMC 4



Structure HCPAITMC 5



Structure HCPAITMC 6

wherein

n is 1 or 2,

T is oxygen or sulfur,

R^1 and R^2 are each independently a C_1 to C_{20} organyl group consisting essentially of inert functional groups,

R^3 is hydrogen or a C_1 to C_{20} organyl group,

R^{11}, R^{12}, R^{13}, R^{14}, R^{21}, R^{22}, R^{23}, and R^{24} are each independently hydrogen or a C_1 to C_{20} organyl group consisting essentially of inert functional groups,

optionally R^{11} or R^{12} and R^{13} or R^{14} are joined to form a ring or ring system,

MX_p represents a transition metal compound where M is chromium, X is a monoanion, and p is an integer from 2 to 6,

Q is a neutral ligand, and

q ranges from 0 to 6.

3. The catalyst system of claim 2, wherein

R^{11} and R^{21} are each independently hydrogen or a C_1 to C_{10} alkyl group, and

R^{12}, R^{13}, R^{14}, R^{22}, R^{23}, and R^{24} are hydrogen.

4. The catalyst system of claim 2, wherein R^3 is hydrogen.

5. The catalyst system of claim 1, wherein the transition metal compound comprises a chromium(III) carboxylate, a chromium(III) β-diketonate, or a chromium(III) halide.

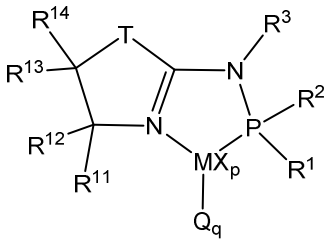
6. The catalyst system of claim 1, wherein the organoaluminum compound comprises an aluminoxane.

7. The catalyst system of claim 6, wherein the aluminoxane comprises methylaluminoxane, a modified methylaluminoxane, ethylaluminoxane, n-propylaluminoxane, iso-propylaluminoxane, n-butylaluminoxane, sec-butylaluminoxane, iso-butylaluminoxane, t-butyl aluminoxane, 1-pentylaluminoxane, 2-pentylaluminoxane, 3-pentylaluminoxane, iso-pentylaluminoxane, neopentylaluminoxane, or mixtures thereof.

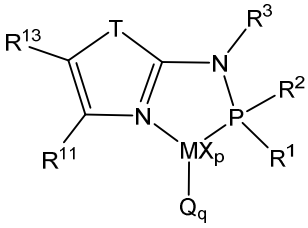
8. The catalyst system of claim 6, wherein the aluminoxane comprises a modified methylaluminoxane.

9. The catalyst system of claim 6, wherein an aluminum of the aluminoxane to transition metal of the heterocyclic 2-[(phosphinyl)aminyl]imine transition metal compound complex molar ratio is in the range of from 10:1 to 5,000:1.

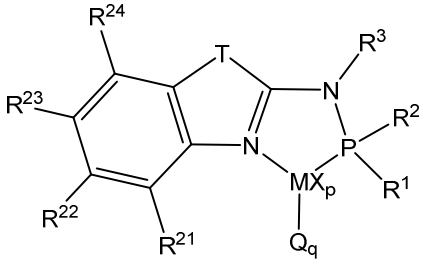
10. The catalyst system of claim 1, wherein the heterocyclic 2-[(phosphinyl)aminyl]imine transition metal compound complex has Structure HCPAITMC 2, Structure HCPAITMC 3, Structure HCPAITMC 4, Structure HCPAITMC 5, or Structure HCPAITMC 6



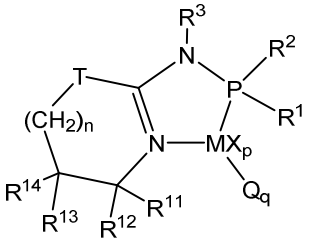
Structure HCPAITMC 2



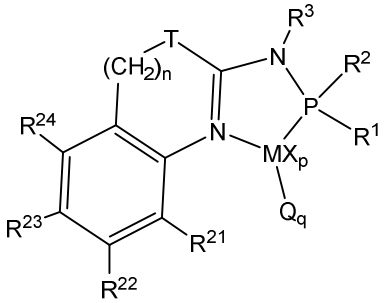
Structure HCPAITMC 3



Structure HCPAITMC 4



Structure HCPAITMC 5



Structure HCPAITMC 6

wherein

n is 1 or 2,

T is oxygen or sulfur,

R^1 and R^2 are each independently a C_1 to C_{20} organyl group consisting essentially of inert functional groups,

R^3 is hydrogen,

R^{11} and R^{21} are each independently hydrogen or a C_1 to C_{10} alkyl group,

R^{12}, R^{13}, R^{14}, R^{22}, R^{23}, and R^{24} are hydrogen,

MX_p is chromium(III) chloride,

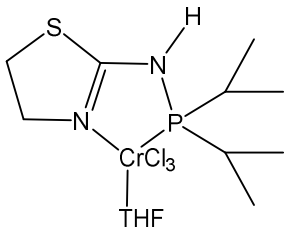
Q is a neutral ligand,

q ranges from 0 to 3,

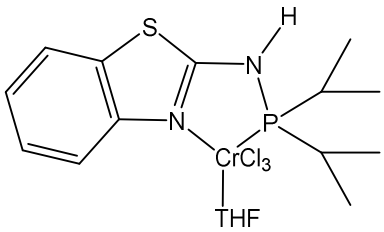
the organoaluminum compound is an aluminoxane, and

an aluminum of the aluminoxane to chromium of the heterocyclic 2-[(phosphinyl)aminyl]imine transition metal compound complex molar ratio is in the range of from 10:1 to 5,000:1.

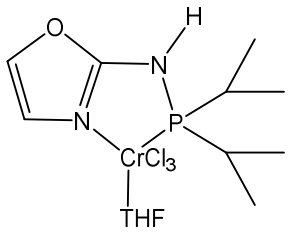
11. The catalyst system of claim 10, wherein the heterocyclic 2-[(phosphinyl)aminyl]imine transition metal compound complex has Structure HCPAICr A, Structure HCPAICr B, or Structure HCPAICr C



Structure HCPAICr A



Structure HCPAICr B



Structure HCPAICr C.

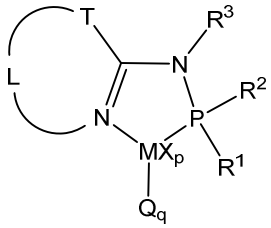
12. A process comprising:

contacting

i) ethylene,

ii) a catalyst system comprising

(a) a heterocyclic 2-[(phosphinyl)aminyl]imine transition metal compound complex having Structure HCPAITMC 1



Structure HCPAITMC 1

wherein

T is oxygen or sulfur,

R^1 and R^2 are each independently a C_1 to C_{20} organyl group consisting essentially of inert functional groups,

R^3 is hydrogen or a C_1 to C_{20} organyl group,

L is a C_1 to C_{20} organylene group consisting essentially of inert functional groups,

MX_p represents a transition metal compound where M is chromium, X is a monoanion, and p is an integer from 1 to 6,

Q is a neutral ligand,

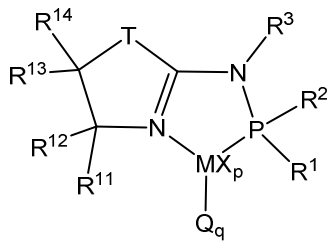
q ranges from 0 to 6, and

(b) an organoaluminum compound, and

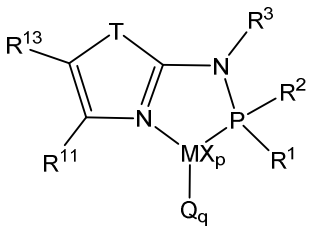
iii) optionally hydrogen

to form an oligomer product.

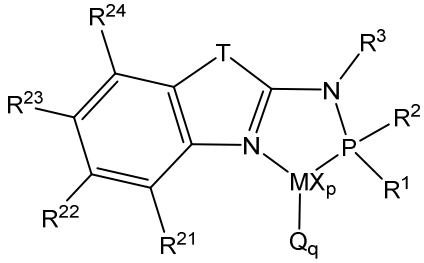
13. The process of claim 12, wherein the heterocyclic 2-[(phosphinyl)aminyl]imine transition metal compound complex has Structure HCPAITMC 2, Structure HCPAITMC 3, Structure HCPAITMC 4, Structure HCPAITMC 5, or Structure HCPAITMC 6



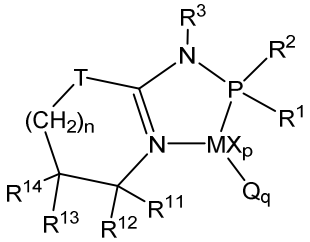
Structure HCPAITMC 2



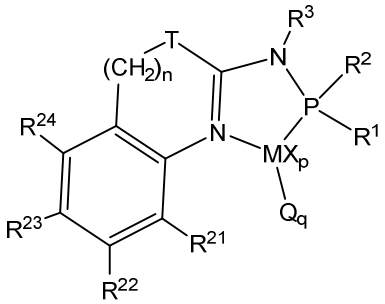
Structure HCPAITMC 3



Structure HCPAITMC 4



Structure HCPAITMC 5



Structure HCPAITMC 6

wherein

n is 1 or 2,

T is oxygen or sulfur,

R^1 and R^2 are each independently a C_1 to C_{20} organyl group consisting essentially of inert functional groups,

R^3 is hydrogen or a C_1 to C_{20} organyl group,

R^{11}, R^{12}, R^{13}, R^{14}, R^{21}, R^{22}, R^{23}, and R^{24} are each independently hydrogen or a C_1 to C_{20} organyl group consisting essentially of inert functional groups,

optionally R^{11} or R^{12} and R^{13} or R^{14} are joined to form a ring or ring system,

MX_p represents a transition metal compound where M is chromium, X is a monoanion, and p is an integer from 1 to 6,

Q is a neutral ligand, and

q ranges from 0 to 6.

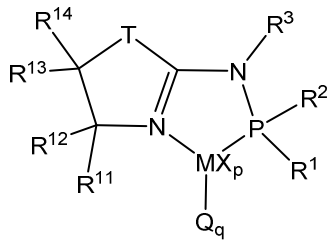
14. The process of claim 12, wherein the process further comprises contacting the heterocyclic 2-[(phosphinyl)aminyl]imine transition metal compound complex and the organoaluminum compound to form a catalyst system mixture, and aging the catalyst system mixture in a substantial absence of ethylene to form an aged catalyst system mixture.

15. The process of claim 14, wherein the catalyst system is aged in the substantial absence of ethylene for from 5 minutes to 6 hours.

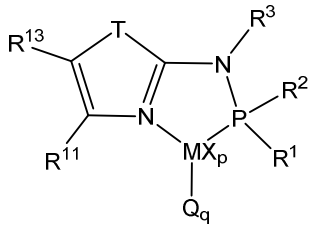
16. The process of claim 12, wherein the transition metal compound comprises a chromium(III) carboxylate, a chromium(III) β-diketonate, or a chromium(III) halide.

17. The process of claim 12, wherein the organoaluminum compound comprises an aluminoxane.

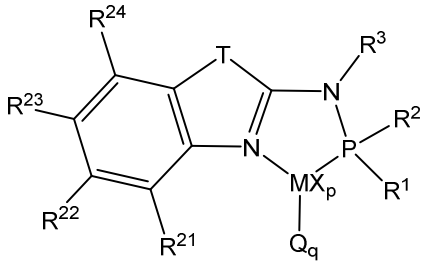
18. The process of claim 12, wherein the heterocyclic 2-[(phosphinyl)aminyl]imine transition metal compound complex has Structure HCPAITMC 2, Structure HCPAITMC 3, Structure HCPAITMC 4, Structure HCPAITMC 5, or Structure HCPAITMC 6



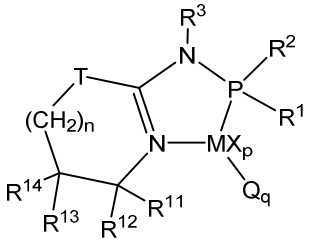
Structure HCPAITMC 2



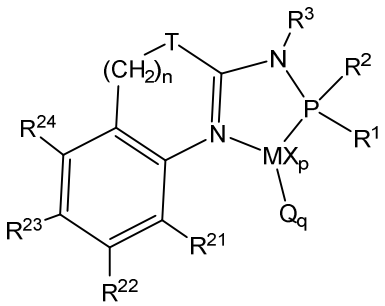
Structure HCPAITMC 3



Structure HCPAITMC 4



Structure HCPAITMC 5



Structure HCPAITMC 6

wherein

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R^3 is hydrogen,

R^{11} and R^{21} are each independently hydrogen or a C_1 to C_{10} alkyl group,

R^{12}, R^{13}, R^{14}, R^{22}, R^{23}, and R^{24} are hydrogen,

MX_p is chromium(III) chloride,

Q is a neutral ligand,

q ranges from 0 to 6, and

the organoaluminum compound is an aluminoxane.

19. The process of claim 18, wherein the oligomer product is formed at

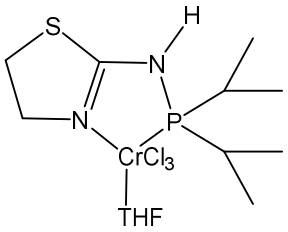
(a) an ethylene partial pressure ranging from 150 psi to 2,000 psi,

(b) a hydrogen partial pressure ranging from 5 psi to 400 psi,

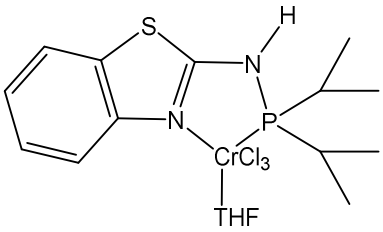
(c) a temperature ranging from 20 °C to 150 °C, and

(d) an aluminum of the aluminoxane to chromium of the heterocyclic 2-[(phosphinyl)aminyl]imine transition metal compound complex molar ratio is in the range of from 10:1 to 5,000:1.

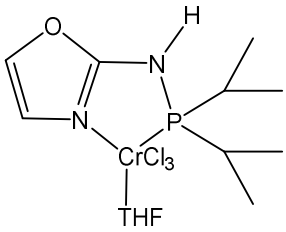
20. The process of claim 19, wherein the heterocyclic 2-[(phosphinyl)aminyl]imine transition metal compound complex has Structure HCPAICr A, Structure HCPAICr B, or Structure HCPAICr C



Structure HCPAICr A



Structure HCPAICr B



Structure HCPAICr C.

21. The process of claim 12, wherein the oligomer product comprises at least 70 wt. % ethylene trimer, ethylene tetramer, or any combination thereof.

22. The process of claim 21, wherein the ethylene trimer comprises at least 85 wt. % 1-hexene

23. The process of claim 21, wherein the ethylene tetramer comprises at least 90 wt. % 1-octene.