CLAIMS:

What is claimed is:

1. A method for producing an olefin polymer comprising:

contacting C_3-C_{40} olefin, ethylene, and diene with a catalyst system comprising activator and a catalyst compound represented by formula (I):

$$T_yCp'_mMG_nX_q \qquad (I)$$

wherein:

Cp' is a tetrahydro-*s*-indacenyl group which is optionally substituted or unsubstituted, provided that when Cp' is tetrahydro-*s*-indacenyl: 1) the 3 and/or 4 positions are not aryl or substituted aryl, 2) the 3 position is not directly bonded to a group 15 or 16 heteroatom, 3) there are no additional rings fused to the tetrahydroindacenyl ligand, 4) T is not bonded to the 2-position, and 5) the 5, 6, or 7-position is geminally disubstituted;

M is a group 3, 4, 5, or 6 transition metal;

T is a bridging group;

y is 0 or 1, indicating the absence or presence of T;

G is a heteroatom group represented by the formula JR^i_{z-y} where J is N, P, O or S,

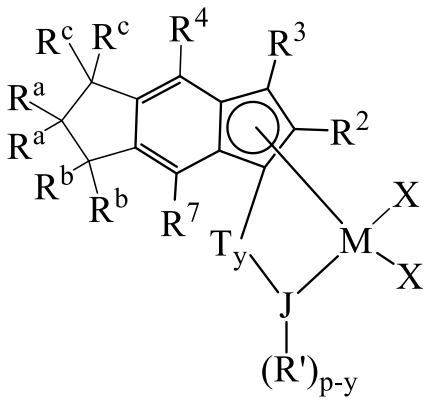
R^i is a C_1 to C_{100} hydrocarbyl group, and z is 2 when J is N or P, and z is 1 when J is O or S;

X is a leaving group;

m = 1; n = 1, 2 or 3; q = 1, 2 or 3; and the sum of m+n+q is equal to the oxidation state of the transition metal; and

obtaining a C_3-C_{40} olefin-ethylene-diene terpolymer comprising from 30 to 55 mol% of ethylene, from 70 to 55 mol% C_3-C_{40} olefin, and from 0.01 to 7 mol% diene, and wherein the T_g of the terpolymer is -28 °C or lower, and the terpolymer produced has a T_g (°C) greater than or equal to -6.886-(87.98*E)+(294*D) and less than or equal to -1.886-(87.98*E)+(294*D) and E is the mole fraction of ethylene in the polymer and D is the mole fraction of diene in the terpolymer.

2. The method of claim 1, wherein the catalyst compound is represented by formula (II):



(II)

where M is a group 4 metal;

J is N, O, S or P;

p is 2 when J is N or P, and is 1 when J is O or S;

each R^a is independently C_1-C_{10} alkyl;

each R^b and R^c is independently hydrogen or a C_1-C_{10} alkyl;

each R^2, R^3, R^4, and R^7 is independently hydrogen, or a C_1-C_{50} substituted or unsubstituted hydrocarbyl, halocarbyl, silylcarbyl or germylcarbyl, provided that: 1) R^3 and/or R^4 are not aryl or substituted aryl, 2) R^3 is not directly bonded to a group 15 or 16 heteroatom, and 3) adjacent R^4, R^c, R^b, R^a, or R^7 do not join together to form a fused ring system;

each R' is independently a C_1-C_{100} substituted or unsubstituted hydrocarbyl, halocarbyl, silylcarbyl or germylcarbyl;

T is a bridging group and y is 0 or 1 indicating the absence (y=0) or presence (y=1) of T;

each X is, independently, a leaving group, or two Xs are joined and bound to the metal atom to form a metallocycle ring, or two Xs are joined to form a chelating ligand, a diene ligand, or an alkylidene.

3. The method of claim 2, wherein both R^a are methyl and all R^b and R^c are hydrogen.

4. The method of claim 2 wherein R^2 is methyl, ethyl, propyl, butyl, pentyl, hexyl, heptyl, octyl, nonyl, decyl, undecyl, dodecyl or an isomer thereof and R^3, R^4, R^2, and

R^7 are hydrogen.

5. The method of claim 2, wherein R^2 is methyl.

6. The method of claim 2 wherein y is 1 and T is $(CR^8R^9)_x$, SiR^8R^9, or GeR^8R^9 where x is 1 or 2, R^8 and R^9 are independently selected from hydrogen or substituted or unsubstituted hydrocarbyl, halocarbyl, silylcarbyl or germylcarbyl.

7. The method of claim 1 wherein M is Ti.

8. The method of claim 1 wherein J is N.

9. The method of clam 2 wherein R' is methyl, ethyl, propyl, butyl, pentyl, hexyl, heptyl, octyl, nonyl, decyl, undecyl, dodecyl, phenyl or an isomer thereof.

10. The method of claim 1 wherein each X is, independently, selected from hydrocarbyl radicals having from 1 to 20 carbon atoms, aryls, hydrides, amides, alkoxides, sulfides, phosphides, halides, amines, phosphines, ethers, or a combination thereof.

11. The method of claim 1 wherein each X is independently selected from halides, aryls or C_1 to C_5 alkyl groups.

12. The method of claim 1, wherein the catalyst is one or more of:
dimethylsilylene(2,6,6-trimethyl-1,5,6,7-tetrahydro-*s*-indacen-1-yl)(t-butylamido)$M(R)_2$;
dimethylsilylene(6,6-dimethyl-1,5,6,7-tetrahydro-*s*-indacen-1-yl)(t-butylamido)$M(R)_2$;
dimethylsilylene(2,7,7-trimethyl-3,6,7,8-tetrahydro-*as*-indacen-3-yl)(t-butylamido)$M(R)_2$;
dimethylsilylene(7,7-dimethyl-3,6,7,8-tetrahydro-*as*-indacen-3-yl)(t-butylamido)$M(R)_2$;

dimethylsilylene(2,6,6-trimethyl-1,5,6,7-tetrahydro-*s*-indacen-1-yl)(cyclododecylamido)M(R)$_2$;
dimethylsilylene(6,6-dimethyl-1,5,6,7-tetrahydro-*s*-indacen-1-yl)(cyclododecylamido)M(R)$_2$;
dimethylsilylene(2,7,7-trimethyl-3,6,7,8-tetrahydro-*as*-indacen-3-yl)(cyclododecylamido)M(R)$_2$;
dimethylsilylene(7,7-dimethyl-3,6,7,8-tetrahydro-*as*-indacen-3-yl)(cyclododecylamido)M(R)$_2$;
dimethylsilylene(2,6,6-trimethyl-1,5,6,7-tetrahydro-*s*-indacen-1-yl)(cyclohexylamido)M(R)$_2$;
dimethylsilylene(6,6-dimethyl-1,5,6,7-tetrahydro-*s*-indacen-1-yl)(cyclohexylamido)M(R)$_2$;
dimethylsilylene(2,7,7-trimethyl-3,6,7,8-tetrahydro-*as*-indacen-3-yl)(cyclohexylamido)M(R)$_2$;
dimethylsilylene(7,7-dimethyl-3,6,7,8-tetrahydro-*as*-indacen-3-yl)(cyclohexylamido)M(R)$_2$;
dimethylsilylene(2,6,6-trimethyl-1,5,6,7-tetrahydro-*s*-indacen-1-yl)(adamantylamido)M(R)$_2$;
dimethylsilylene(6,6-dimethyl-1,5,6,7-tetrahydro-*s*-indacen-1-yl)(adamantylamido)M(R)$_2$;
dimethylsilylene(2,7,7-trimethyl-3,6,7,8-tetrahydro-*as*-indacen-3-yl)(adamantylamido)M(R)$_2$;
dimethylsilylene(7,7-dimethyl-3,6,7,8-tetrahydro-*as*-indacen-3-yl)(adamantylamido)M(R)$_2$;
dimethylsilylene(2,6,6-trimethyl-1,5,6,7-tetrahydro-*s*-indacen-1-yl)(neopentylamido)M(R)$_2$;
dimethylsilylene(6,6-dimethyl-1,5,6,7-tetrahydro-*s*-indacen-1-yl)(neopentylamido)M(R)$_2$;
dimethylsilylene(2,7,7-trimethyl-3,6,7,8-tetrahydro-*as*-indacen-3-yl)(neopentylamido)M(R)$_2$;
dimethylsilylene(7,7-dimethyl-3,6,7,8-tetrahydro-*as*-indacen-3-yl)(neopentylamido)M(R)$_2$;

dimethylsilylene(2-methyl-6,6-diethyl-1,5,6,7-tetrahydro-*s*-indacen-1-yl)(t-butylamido)$M(R)_2$;
dimethylsilylene(6,6-diethyl-1,5,6,7-tetrahydro-*s*-indacen-1-yl)(t-butylamido)$M(R)_2$;
dimethylsilylene(2-methyl-7,7-diethyl-3,6,7,8-tetrahydro-*as*-indacen-3-yl)(t-butylamido)$M(R)_2$;
dimethylsilylene(7,7-diethyl-3,6,7,8-tetrahydro-*as*-indacen-3-yl)(t-butylamido)$M(R)_2$;
dimethylsilylene(2-methyl-6,6-diethyl-1,5,6,7-tetrahydro-*s*-indacen-1-yl)(cyclododecylamido)$M(R)_2$;
dimethylsilylene(6,6-diethyl-1,5,6,7-tetrahydro-*s*-indacen-1-yl)(cyclododecylamido)$M(R)_2$;
dimethylsilylene(2-methyl-7,7-diethyl-3,6,7,8-tetrahydro-*as*-indacen-3-yl)(cyclododecylamido)$M(R)_2$;
dimethylsilylene(7,7-dimethyl-3,6,7,8-tetrahydro-*as*-indacen-3-yl)(cyclododecylamido)$M(R)_2$;
diethylsilylene(2,6,6-trimethyl-1,5,6,7-tetrahydro-*s*-indacen-1-yl)(t-butylamido)$M(R)_2$;
diethylsilylene(6,6-dimethyl-1,5,6,7-tetrahydro-*s*-indacen-1-yl)(t-butylamido)$M(R)_2$;
diethylsilylene(2,7,7-trimethyl-3,6,7,8-tetrahydro-*as*-indacen-3-yl)(t-butylamido)$M(R)_2$;
diethylsilylene(7,7-dimethyl-3,6,7,8-tetrahydro-*as*-indacen-3-yl)(t-butylamido)$M(R)_2$;
dimethylsilylene(2-methyl-3,6,7,8-tetrahydro-*as*-indacen-3-yl)(cyclohexylamido)$M(R)_2$;
dimethylsilylene(2-methyl-3,6,7,8-tetrahydro-*as*-indacen-3-yl)(cyclododecylamido)$M(R)_2$;
dimethylsilylene(2-methyl-3,6,7,8-tetrahydro-*as*-indacen-3-yl)(adamantylamido)$M(R)_2$; and
dimethylsilylene(2-methyl-3,6,7,8-tetrahydro-*as*-indacen-3-yl)(t-butylamido)$M(R)_2$;

where M is selected from a group consisting of Ti, Zr, and Hf and R is selected from halogen or C_1 to C_5 alkyl.

13. The method of claim 1, wherein the catalyst is one or more of:

dimethylsilylene(2,7,7-trimethyl-3,6,7,8-tetrahydro-*as*-indacen-3-yl)(t-butylamido)titanium dimethyl; or dimethylsilylene(2,6,6-trimethyl-1,5,6,7-tetrahydro-*s*-indacen-1-yl)(t-butylamido)titanium dimethyl.

14. The method of claim 1, wherein the activator comprises one or more of: N,N-dimethylanilinium tetrakis(perfluoronaphthyl)borate, N,N-dimethylanilinium tetrakis(perfluorobiphenyl)borate, N,N-dimethylanilinium tetrakis(perfluorophenyl)borate, N,N-dimethylanilinium tetrakis(3,5-bis(trifluoromethyl)phenyl)borate, triphenylcarbenium tetrakis(perfluoronaphthyl)borate, triphenylcarbenium tetrakis(perfluorobiphenyl)borate, triphenylcarbenium tetrakis(3,5-bis(trifluoromethyl)phenyl)borate, triphenylcarbenium tetrakis(perfluorophenyl)borate, $[Me_3NH^+][B(C_6F_5)^{4-}]$, 1-(4-(tris(pentafluorophenyl)borate)-2,3,5,6-tetrafluorophenyl) pyrrolidinium; $[Me_3NH^+][B(C_6F_5)^{4-}]$, 1-(4-(tris(pentafluorophenyl)borate)-2,3,5,6-tetrafluorophenyl) pyrrolidinium, sodium tetrakis(pentafluorophenyl)borate, potassium tetrakis(pentafluorophenyl)borate, 4-(tris(pentafluorophenyl)borate)-2,3,5,6-tetrafluoropyridinium, sodium tetrakis(perfluorophenyl)aluminate, potassium tetrakis(pentafluorophenyl), and N,N-dimethylanilinium tetrakis(perfluorophenyl)aluminate.

15. The method of claim 1, wherein the C_3-C_{40} olefin is a C_3-C_{20} α-olefin selected from propylene, 1-butene, 1-pentene, 1-hexene, 1-heptene, 1-octene, 1-nonene, 1-decene, 1-undecene, 1-dodecene and isomers thereof.

16. The method of claim 1, wherein the C_3-C_{20} α-olefin is propylene, and the diene is one or more of 5-ethylidene-2-norbornene; 1,4-hexadiene; 5-methylene-2-norbornene; 1,6-octadiene; 5-methyl-l,4- hexadiene; 3,7-dimethyl-1,6-octadiene; dicyclopentadiene; and combinations thereof.

17. The method of claim 1, the catalyst has an efficiency greater than 10,000 g polymer/g catalyst.

18. The method of claim 1, wherein the contacting occurs at a temperature of from 0°C to 300°C, at a pressure from 0.35 MPa to 16 MPa.

19. The method of claim 1, wherein the polymer produced has:
1) a crystallinity of from 0% to 3%; and
2) a melt flow rate at 230°C from 0.2 g/10min to 100 g/10 min.

20. The method of claim 19, wherein the polymer produced has a g' value of 0.90 or greater.

21. The method of claim 19, wherein the polymer produced has a number average molecular weight value of from 40,000 g/mol to 250,000 g/mol, a weight average molecular weight value of from 50,000 g/mol to 500,000 g/mol, and a z-average molecular weight value of from 150,000 g/mol to 800,000 g/mol.

22. The method of claim 19, wherein the polymer produced has an Mw/Mn of from 1.5 to 3.

23. The method of claim 21, wherein the polymer has a glass transition temperature of from -29°C to -53°C.

24. The method of claim 1, wherein the feed concentration of monomers, comonomers, and hydrogen for the polymerization is from 1 wt% to 10 wt% ethylene in solvent, from 1 wt% to 20 wt% propylene in solvent, from 0.5 wt% to 5 wt% ENB in solvent, and from 0 wt% to 0.5 wt% hydrogen in solvent, based on the total mass flow rate of the feedstream.

25. The method of claim 1 wherein the feed concentration of monomers, comonomers, and hydrogen for the polymerization is from 1 wt% to 10 wt% ethylene in solvent, from 1 wt% to 20 wt% propylene in solvent, from 0.5 wt% to 5 wt% ENB in solvent, and from 0 wt% to 0.5 wt% hydrogen in solvent, based on the total mass flow rate of the feedstream, wherein the solvent is hexane and or isohexane.