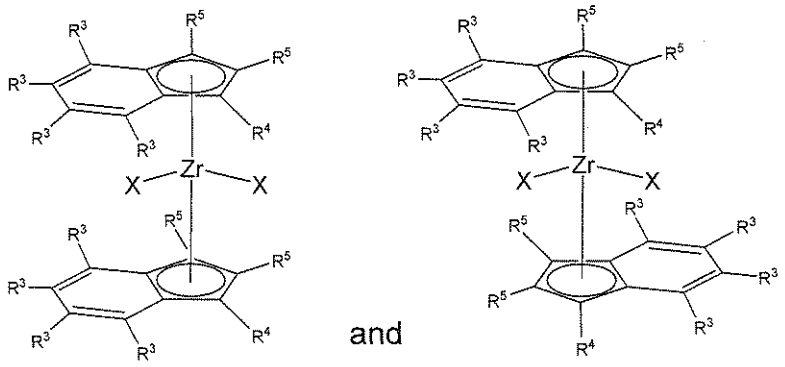
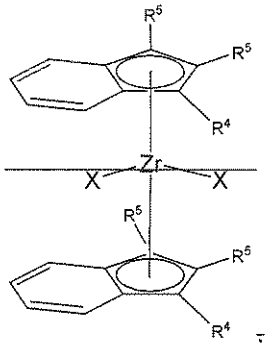


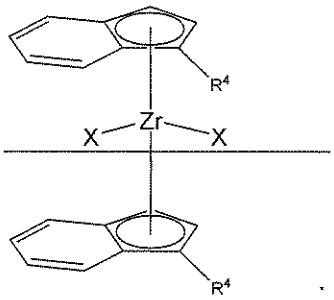
MESO RAC ,

wherein the ratio of the meso enantiomer to the rac enantiomer is substantially normalized during alkylation to between about 1.0 and about 1.2, wherein each R^3 is independently H, a hydrocarbyl group, a substituted hydrocarbyl group, or a heteroatom group; R^4 is a hydrocarbyl group, a substituted hydrocarbyl group, or a heteoatom group; each R^5 is independently H, a hydrocarbyl group, a substituted hydrocarbyl group, or a heteroatom group; wherein R^3, R^4, and R^5 may be the same or different; and each X is a methyl group.

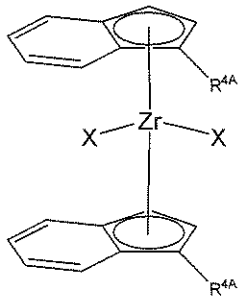
~~8. The catalyst composition of claim 7, wherein the second catalyst compound comprises a compound with the following formula:~~



~~9. The catalyst composition of claim 7, wherein the second catalyst compound comprises at least one compound with the following formula:~~

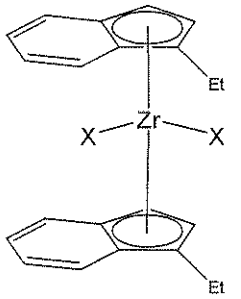


8~~10~~. The catalyst composition of claim 7, wherein the second catalyst compound comprises at least one compound with the following formula:



wherein each R^{4A} is independently a methyl, ethyl, propyl, pentyl, hexyl, octyl, nonyl, dodecyl, phenethyl, or other hydrocarbyl.

9~~11~~. The catalyst composition of claim 7, wherein the second catalyst compound comprises at least one compound with the following formula:



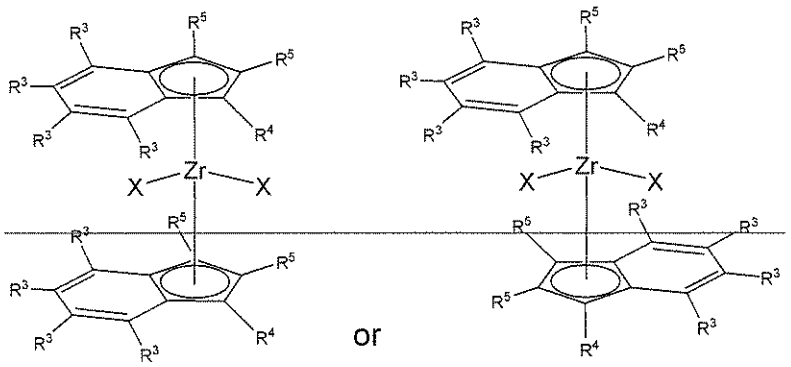
10~~2~~. The catalyst composition of claim 7, comprising a third catalyst.

~~13. A method of polymerizing olefins to produce a polyolefin polymer with a multimodal composition distribution, comprising contacting ethylene and a comonomer with a catalyst system, wherein the catalyst system comprises a first catalyst compound and a second catalyst compound that are co-supported to form a commonly supported catalyst system, wherein the first catalyst compound comprises the following formula:~~

~~$(C_5H_aR^1_b)(C_5H_cR^2_d)HfX_2$~~

~~wherein each R^1 is independently H, a hydrocarbyl group, a substituted hydrocarbyl group, or a heteroatom group; each R^2 is independently H, a hydrocarbyl group, a substituted hydrocarbyl~~

group, or a heteroatom group; a and c are ≥ 3; a+b = c+d = 5; at least one R^1 and at least one R^2 is a hydrocarbyl or substituted hydrocarbyl group; adjacent groups R^1 and R^2 groups may be coupled to form a ring; and each X is independently a leaving group selected from a labile hydrocarbyl, substituted hydrocarbyl, or heteroatom group; and the second catalyst compound comprises a mixture of enantiomers:



MESO RAC

;

wherein the meso enantiomer is at least about 15 parts in the mixture, the rac enantiomer is less than about 5 parts in the mixture, wherein each R^3 is independently H, a hydrocarbyl group, a substituted hydrocarbyl group, or a heteroatom group; R^4 is a hydrocarbyl group, a substituted hydrocarbyl group, or a heteoatom group; each R^5 is independently H, a hydrocarbyl group, a substituted hydrocarbyl group, or a heteroatom group; wherein R^3, R^4, and R^5 may be the same or different; and each X is independently a leaving group selected from a labile hydrocarbyl, a substituted hydrocarbyl, a heteroatom group, or a divalent radical that links to an R^3, R^4, or R^5 group.

14. The method of claim 13, wherein the X group is methyl, and the meso / rac ratio is adjusted by methylation with a solution of about 2.3 equivalents of MeLi in ether relative to the catalyst compound.

15. The method of claim 13, comprising forming a product from the polyolefin polymer.

16. The method of claim 13, comprising continuously combining a catalyst component slurry with a catalyst component solution to form the commonly supported catalyst system.

17. The method of claim 16, wherein the catalyst component slurry comprises the first catalyst compound and the catalyst component solution comprises the second catalyst compound.

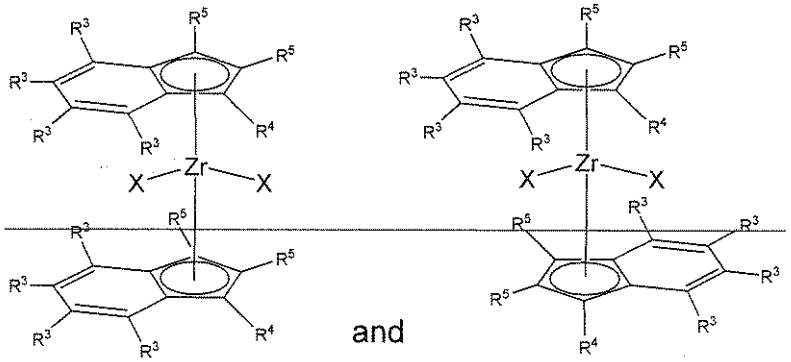
18. The method of claim 13, comprising adjusting a ratio of the comonomer to ethylene within a polymerization reactor to control a composition distribution, a molecular weight distribution, a melt index (I_2), or a ratio of two melt indices, or any combinations thereof, of the polyolefin polymer.

19. The method of claim 13, comprising adjusting a ratio of the hydrogen to ethylene within a polymerization reactor to control a composition distribution, a molecular weight distribution, a melt index (I_2), or a ratio of two melt indices, or any combinations thereof, of the polyolefin polymer.

20. A polyolefin polymer comprising ethylene and an alpha-olefin having 4 to 20 carbon atoms, wherein the polefin polymer is formed using a catalyst blend comprising a first catalyst compound and a second catalyst compound that are co-supported forming a commonly supported catalyst system, wherein the first catalyst compound comprises the following formula:

$$(C_5H_aR^1_b)(C_5H_eR^2_d)HfX_2$$

wherein each R^1 is independently H, a hydrocarbyl group, a substituted hydrocarbyl group, or a heteroatom group; each R^2 is independently H, a hydrocarbyl group, a substituted hydrocarbyl group, or a heteroatom group; a and c are ≥ 3; a+b = c+d = 5; at least one R^1 and at least one R^2 is a hydrocarbyl or substituted hydrocarbyl group; adjacent groups R^1 and R^2 groups may be coupled to form a ring; and each X is independently a leaving group selected from a labile hydrocarbyl, substituted hydrocarbyl, or heteroatom group; and the second catalyst compound comprises a mixture of enantiomers:



MESO RAC ;

wherein the ratio of one enantiomer to the other enantiomer at least about 3, wherein each R^3 is independently H, a hydrocarbyl group, a substituted hydrocarbyl group, or a heteroatom group; R^4 is a hydrocarbyl group, a substituted hydrocarbyl group, or a heteoatom group; each R^5 is independently H, a hydrocarbyl group, a substituted hydrocarbyl group, or a heteroatom group; wherein R^3, R^4, and R^5 may be the same or different; and each X is independently a leaving group selected from a methyl group or a benzyl group.

21. The polyoefin polymer of claim 20, wherein the meso enantiomer is about 19 parts in the mixture, and the rac enantiomer is about 1 part in the mixture.

22. A method of forming a catalyst composition, comprising:

dissolving 1-ethylindenyllithium in dimethoxyethane to form a precursor solution;

cooling the precursor solution to about -20 °C;

adding solid $ZrCl_4$ over about five minutes to start a reaction;

continuing the reaction overnight;

removing volatiles to form a raw product;

extracting the raw product with CH_2Cl_2; and

removing the CH_2Cl_2 under vacuum to form a mixture comprising about 19 parts meso-$(1\text{-EtInd})_2ZrCl_2$ and about 1 part rac-$(1\text{-EtInd})_2ZrCl_2$.

23. The method of claim 22, comprising:

slurrying the mixture in Et_2O;

adding at least about 2.3 equivalents of RMgBr dissolved in ether to the slurry, wherein R is a benzyl group, a methyl group, or a mixture thereof;

drying the slurry;

extracting with warm hexanes; and

filtering to form a catalyst component comprising about 19 parts meso-$(1\text{-EtInd})_2ZrR_2$ and about 1 part rac-$(1\text{-EtInd})_2ZrR_2$.

24. The method of claim 23, comprising:

fluidizing a catalyst support with an inert gas;

heating the support to remove any adsorbed water to form a dried support; and

storing the dried support under an inert gas.

25. The method of claim 24, comprising:

forming a slurry of the dried support in a mixture of toluene and methylaluminoxane; and

drying the mixture to form methyl amluminoxane supported on silica (SMAO).

26. The method of claim 25, comprising:

adding pentane to the SMAO to form a slurry;

dissolving the catalyst component in toluene to form a toluene solution;

adding the toluene solution to the slurry to form a catalyst;

filtering the catalyst from the slurry; and

drying the catalyst.