Claims

What is claimed is:

1. A process to produce a poly alpha olefin (PAO), the process comprising:

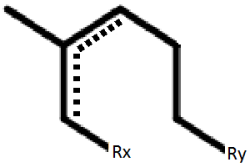
   a. contacting a catalyst, an activator, and a monomer in a first reactor to obtain a first reactor effluent, the effluent comprising a dimer product, a trimer product, and optionally a higher oligomer product,

   b. feeding at least a portion of the dimer product to a second reactor,

   c. contacting said dimer product with a second catalyst, a second activator, and optionally a second monomer in the second reactor, and

   d. obtaining a second reactor effluent comprising a PAO,

   wherein the dimer product of the first reactor effluent contains at least 25 wt% of tri-substituted vinylene represented by the following structure:



   and the dashed line represents the two possible locations where the unsaturated double bond may be located and Rx and Ry are independently selected from a C_3 to C_{21} alkyl group;

   wherein said catalyst in said first reactor is represented by the following formula $X_1X_2M_1(CpCp^*)M_2X_3X_4$ and wherein:

   M_1 is an optional bridging element;

   M_2 is a Group 4 metal;

   Cp and Cp* are the same or different substituted or unsubstituted cyclopentadienyl ligand systems, or are the same or different substituted or unsubstituted indenyl or tetrahydroindenyl rings wherein, if substituted, the substitutions may be independent or linked to form multicyclic structures;

   X_1 and X_2 are independently hydrogen, hydride radicals, hydrocarbyl radicals, substituted hydrocarbyl radicals, silylcarbyl radicals, substituted silylcarbyl radicals, germylcarbyl radicals, or substituted germylcarbyl radicals; and

   X_3 and X_4 are independently hydrogen, halogen, hydride radicals, hydrocarbyl radicals, substituted hydrocarbyl radicals, halocarbyl radicals, substituted

halocarbyl radicals, silylcarbyl radicals, substituted silylcarbyl radicals, germylcarbyl radicals, or substituted germylcarbyl radicals; or both X_3 and X_4 are joined and bound to the metal atom to form a metallacycle ring containing from about 3 to about 20 carbon atoms.

2. The process of claim 1, including the step of separating the at least a portion of the dimer product from the trimer and optional higher oligomer products prior to feeding said dimer product to the second reactor.

3. The process of claim 1 or 2, wherein said portion of dimer product from the first reactor is fed directly into the second reactor.

4. The process of any one of claims 1 to 3, wherein the first reactor effluent contains less than 70 wt% of di-substituted vinylidene represented by the following formula:

$$RqRzC=CH_2$$

wherein Rq and Rz are independently selected from alkyl groups.

5. The process of any one of claims 1 to 4, wherein the dimer product of the first reactor effluent contains greater than 50 wt% of tri-substituted vinylene dimer.

6. The process of any one of claims 1 to 5, wherein the second reactor effluent has a product having a carbon count of C_{28}-C_{32}, wherein said product comprises at least 70 wt% of said second reactor effluent.

7. The process of any one of claims 1 to 6, wherein the second reactor effluent has a kinematic viscosity at 100°C in the range selected from 1 to 150 cSt, 1 to 20 cSt, 1 to 3.6 cSt, 40 to 150 cSt, or 60 to 100 cSt.

8. The process of any one of claims 1 to 7, wherein monomer is fed into the second reactor, and the monomer is a linear alpha olefin selected from the group including 1-hexene, 1-octene, 1-nonene, 1-decene, 1-dodecene, and 1-tetradecene.

9. The process of any one of claims 1 to 8, wherein the second catalyst is a Lewis acid and at least two co-activators are present during the second contacting step.

10. The process of any one of claims 1 to 9, wherein the contacting in the first reactor occurs without the addition of hydrogen to the reactor.

11. The process of any one of claims 1 to 10, wherein the first step of contacting occurs by contacting the catalyst, activator system, and monomer wherein the catalyst is represented by the formula of

$$X_1X_2M_1(CpCp^*)M_2X_3X_4$$

wherein

M_1 is a bridging element of silicon,

M_2 is the metal center of the catalyst,

Cp and Cp* are the same or different substituted or unsubstituted indenyl or tetrahydroindenyl rings that are each bonded to both M_1 and M_2, and

X_1, X_2, X_3, and X_4 are independently selected from hydrogen, branched or unbranched C_1 to C_{20} hydrocarbyl radicals, or branched or unbranched substituted C_1 to C_{20} hydrocarbyl radicals; and

the activator system is a combination of an activator and co-activator, wherein the activator is a non-coordinating anion, and the co-activator is a tri-alkylaluminum compound wherein the alkyl groups are independently selected from C_1 to C_{20} alkyl groups, wherein the molar ratio of activator to transition metal compound is in the range of 0.1 to 10 and the molar ratio of co-activator to transition metal compound is 1 to 1000, and

the catalyst, activator, co-activator, and monomer are contacted in the absence of hydrogen, at a temperature of 80°C to 150°C, and with a reactor residence time of 2 minutes to 6 hours.

12. The process of any one of claims 1 to 11, wherein the first reactor effluent is, after optional removal of unreacted monomers, a PAO having a kinematic viscosity at 100°C (KV_{100}) of less than 20 cSt.

13. The process of any one of claims 1 to 12, wherein a portion of the dimer from the first reactor effluent is subject to a distillation process.

14. The process of any one of claims 1 to 13, wherein the portion of the dimer product from the first reactor is not subject to a separate isomerization process following oligomerization and before feeding said portion to the second reactor.

15. The process of any one of claims 1 to 14, wherein, after hydrogenation, the trimer portion of the first reactor effluent has at least one or any combination of the following properties : i) viscosity index (VI) of greater than 125, ii) a Noack volatility of not greater than 14 wt%, or iii) a kinematic viscosity at 100°C of less than 4 cSt.

16. The process of any one of claims 1 to 15, wherein the trimer and higher oligomer portions of the first reactor effluent has at least one or any combination of the following properties: i) a VI of greater than 130, ii) a Noack volatility of not greater than 6 wt%, or iii) a KV_{100} of less than 25 cSt.

17. The process of any one of claims 1 to 16, wherein the monomer contacted in the first reactor is comprised of at least one linear alpha olefin wherein the linear alpha olefin is selected from at least one of 1-hexene, 1-octene, 1-nonene, 1-decene, 1-dodecene, 1-tetradecene, and combinations thereof.

18. The process of any one of claims 1 to 17, wherein a portion of the second reactor effluent is a PAO having a kinematic viscosity at 100°C of not more than 3.2 cSt and a Noack volatility of not more than 19 wt%.

19. The process of any one of claims 1 to 18, wherein a portion of the second reactor effluent is a PAO having a carbon count of C_{28}-C_{32} and said portion has a pour point of less than -60°C.

20. The process of any one of claims 1 to 17, wherein a portion of the second reactor effluent is a PAO having a kinematic viscosity at 100°C of not more than 4.1 cSt and a Noack volatility of not more than 9 wt%.

21. The process of any one of claims 1 to 17, wherein a portion of the second reactor effluent is a PAO having a carbon count of C_{28}-C_{32} and said portion has a kinematic viscosity at 100°C of not more than 10 cSt.

22. The process of any one of claims 1 to 21, wherein the PAO of the second reactor effluent, prior to hydrogenation, is comprised of at least 15 wt% of tetra-substituted olefins.

23. The process of any one of claims 1 to 21, wherein the PAO of the second reactor effluent, prior to hydrogenation, is comprised of at least 60 wt% tri-substituted olefins.

24. A poly alpha olefin (PAO) obtained by the process of any one of claims 1 to 24, wherein the PAO has a kinematic viscosity at 100°C of not more than 3.2 cSt and a Noack volatility of not more than 19 wt%.

25. A poly alpha olefin (PAO) obtained by the process of any one of claims 1 to 24, wherein the PAO has a kinematic viscosity at 100°C of not more than 4.1 cSt and a Noack volatility of not more than 9 wt%.