

HALOGENATED AMIDE ESTER AND INTERNAL ELECTRON DONOR WITH SAME

BACKGROUND

[0001] The present disclosure relates to halogenated amide esters, and procatalyst compositions and catalyst compositions containing the same.

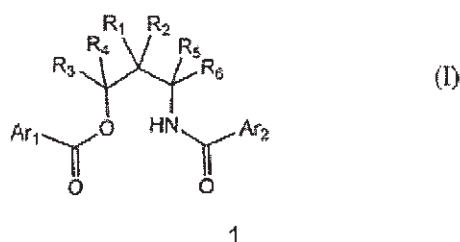
[0002] Worldwide demand for olefin-based polymers continues to grow as applications for these polymers become more diverse and more sophisticated. Olefin-based polymers with broad molecular weight distribution (MWD), for example, find increasing applications in thermoforming; pipe-, foam-, blow-molding; and films. Known are Ziegler-Natta catalyst compositions for the production of olefin-based polymers, particularly propylene-based polymers, with broad MWD. Ziegler-Natta catalyst compositions typically include a procatalyst composed of a transition metal halide (i.e., titanium, chromium, vanadium) supported on a metal or metalloid compound, such as magnesium chloride or silica, the procatalyst complexed with a cocatalyst such as an organoaluminum compound. Production of olefin-based polymers with broad MWD produced by way of Ziegler-Natta catalysts, however, is typically limited to a single reactor process requiring rigorous process control and/or a series reactor process requiring multiple reactors.

[0003] Given the perennial emergence of new applications for olefin-based polymers, the art recognizes the need for olefin-based polymers with improved and varied properties. Desirable would be a Ziegler-Natta catalyst composition that produces olefin-based polymer, and propylene-based polymer in particular, with broad molecular weight distribution (MWD) with less process constraints and less equipment.

SUMMARY

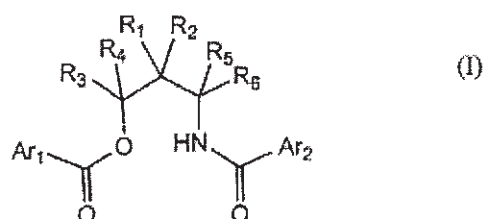
[0004] The present disclosure is directed to halogenated amide esters, and the use of same in procatalyst and catalyst compositions. Catalyst compositions containing the halogenated amide ester find application in olefin polymerization processes. The present halogenated amide ester-containing catalyst compositions have high catalyst activity, high selectivity, and produce propylene-based olefins with high isotacticity and broad molecular weight distribution.

[0005] With the foregoing in view, the invention, in its broadest aspect resides in a halogenated amide ester having the structure (I)



[0006] wherein R_1 - R_6 are the same or different each of R_1 - R_6 is selected from the group consisting of hydrogen, a halogen, and an acyclic alkyl group having 1-20 carbon atoms and at least one of R_1 - R_6 is an acyclic alkyl group; and Ar_1 and Ar_2 are the same or different and each of Ar_1 and Ar_2 is selected from the group consisting of an aryl group having 6-20 carbon atoms, and an arylalkyl group having 7-20 carbon atoms and at least one of Ar_1 and Ar_2 is halogenated.

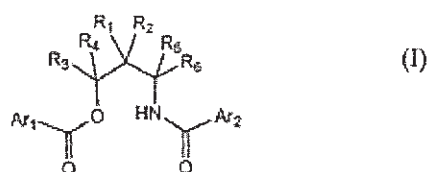
[0007] In another aspect the invention resides in a procatalyst composition comprising a combination of a magnesium moiety, a titanium moiety and an internal electron donor comprising a halogenated amide ester of structure (I)



[0008] wherein R_1 - R_6 are the same or different, each of R_1 - R_6 is selected from the group consisting of hydrogen, halogen, a hydrocarbyl group having 1-20 carbon atoms, and a substituted hydrocarbyl group having 1-20 carbon atoms; and Ar_1 and Ar_2 are the same or different and each of Ar_1 and Ar_2 is selected from the group consisting of an aryl group having 6-20 carbon atoms and an arylalkyl group having 7-20 carbon atoms and at least one of Ar_1 and Ar_2 is halogenated.

[0009] In another aspect the invention resides in a catalyst comprising a procatalyst composition as specified herein and a cocatalyst. The procatalyst composition includes an internal electron donor that is a halogenated amide ester. The halogenated amide ester has the structure (I).

[0010] In another aspect the invention resides in a process for producing an olefin based polymer comprising contacting, under polymerization conditions, an olefin with a catalyst composition comprising a halogenated amide ester of structure (I).



[0011] wherein R_1 - R_6 are the same or different, each of R_1 - R_6 is selected from the group consisting of hydrogen, halogen, a hydrocarbyl group having 1-20 carbon atoms, and a substituted hydrocarbyl group having 1-20 carbon atoms; and Ar_1 and Ar_2 are the same or different and each of Ar_1 and Ar_2 is selected from a group consisting of an aryl group having 6-20 carbon atoms and an arylalkyl group

having 7-20 carbon atoms, and at least one of Ar₁ and Ar₂ is halogenated; and forming an olefin-based polymer comprising the halogenated amide ester.

[0012] An advantage of the present disclosure is the provision of an improved procatalyst composition and another advantage of the present disclosure is the provision of an improved catalyst composition for the polymerization of olefin-based polymers.

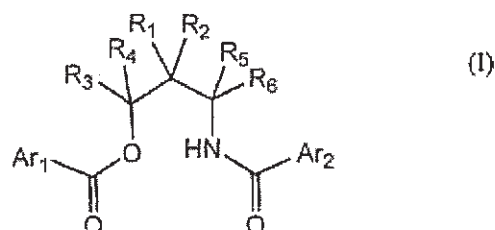
[0013] An advantage of the present disclosure is the provision of a phthalate-free catalyst composition and a phthalate-free olefin-based polymer produced therefrom.

[0014] An advantage of the present disclosure is a catalyst composition that produces a propylene-based polymer with broad molecular weight distribution and/or high isotacticity.

[0015] An advantage of the present disclosure is a catalyst composition that produces a propylene-based polymer with broad molecular weight distribution in a single reactor.

DETAILED DESCRIPTION

[0016] The present disclosure is directed to a halogenated amide ester and procatalyst/catalyst compositions containing the same and olefin-based polymers produced therefrom. The term "halogenated amide ester," as used herein is an amide ester having the structure (I):



[0017] wherein R₁-R₆ are the same or different. Each of R₁-R₆ is selected from hydrogen, a halogen, and a hydrocarbyl group having 1-20 carbon atoms. Ar₁ and Ar₂ are the same or different. Each of Ar₁ and Ar₂ is selected from an aryl group having 6-20 carbon atoms and an arylalkyl group having 7-20 carbon atoms. At least one of Ar₁ and Ar₂ is halogenated. In other words, at least one halogen atom (F, Cl, Br, I) is bonded to either Ar₁ and/or Ar₂.

[0018] Two or more of R₁-R₆ may link to form a mono-cyclic or a poly-cyclic structure. Ar₁ and/or Ar₂ may be a mono-aromatic or a poly-aromatic structure. Ar₁ and/or Ar₂ may

also include straight, branched, acyclic or cyclic substituents. Nonlimiting examples for Ar₁ and/or Ar₂ include a phenyl group, a naphthyl group, an anthracenyl group, and a phenanthrenyl group.

[0019] As used herein, the term "hydrocarbyl" or "hydrocarbon" is a substituent containing only hydrogen and carbon atoms, including branched or unbranched, saturated or unsaturated, cyclic, polycyclic, fused, or acyclic species, and combinations thereof. Nonlimiting examples of hydrocarbyl groups include alkyl-, cycloalkyl-, alkenyl-, alkadienyl-, cycloalkenyl-, cycloalkadienyl-, aryl-, aralkyl, alkylaryl-, and alkynyl- groups.

[0020] As used herein, the term "substituted hydrocarbyl" or "substituted hydrocarbon" is a hydrocarbyl group that is substituted with one or more nonhydrocarbyl substituent groups. A nonlimiting example of a nonhydrocarbyl substituent group is a heteroatom. As used herein, a "heteroatom" is an atom other than carbon or hydrogen. The heteroatom can be a non-carbon atom from Groups IV, V, VI, and VII of the Periodic Table. Nonlimiting examples of heteroatoms include: halogens (F, Cl, Br, I), N, O, P, B, S, and Si. A substituted hydrocarbyl group also includes a halohydrocarbyl group and a silicon-containing hydrocarbyl group. As used herein, the term "halohydrocarbyl" group is a hydrocarbyl group that is substituted with one or more halogen atoms.

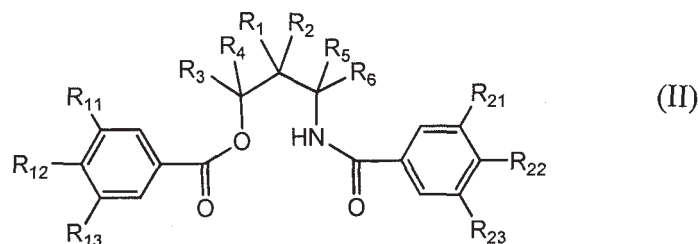
[0021] In an embodiment, at least one, or at least two, or at least three, of R₁-R₆ is/are a hydrocarbyl group having 1-20 carbon atoms. In a further embodiment, each of R₁ and R₂ is a hydrocarbyl group having 1-20 carbon atoms, or a hydrocarbyl group having 1-6 carbon atoms.

[0022] In another embodiment, each of R₃ and R₅ is a hydrocarbyl group having 1-20 carbon atoms, or a hydrocarbyl group having 1-6 carbon atoms.

[0023] The present disclosure provides a halogenated amide ester. In an embodiment, the halogenated amide ester of structure (I) includes R₁-R₆, each being the same or different. Each of R₁-R₆ is selected from hydrogen, a halogen, and an acyclic alkyl group having 1-20 carbon atoms, or 1-6 carbon atoms. At least one of, or at least two of R₁-R₆ is/are an acyclic alkyl group. The acyclic alkyl group may be substituted with a member selected from a halogen, a silicon atom, and combinations thereof.

[0024] Ar₁ and Ar₂ are aryl groups and/or arylalkyl groups as discussed above with at least one of or each of, Ar₁ and Ar₂ being halogenated.

[0025] In an embodiment, the halogenated amide ester has the structure (II):



[0026] wherein at least one of R_{11} - R_{13} and at least one of R_{21} - R_{23} is a halogen atom.

[0027] In an embodiment, each of R_{12} and R_{22} of structure (II) is selected from chlorine and/or fluorine.

[0028] In an embodiment, each of R_{12} and R_{22} of structure (II) is selected from chlorine (chlorinated amide ester) and/or fluorine (fluorinated amide ester) and at least one of, or at least two of, R_1 - R_6 is/are a hydrocarbyl group having 1-20 carbon atoms. In a further embodiment, each of R_1 and R_2 is a hydrocarbyl group having 1-20 carbon atoms, or a hydrocarbyl group having 1-6 carbon atoms.

[0029] In an embodiment, each of R_{12} - R_{22} of structure (II) is selected from chlorine and/or fluorine. Each of R_3 and R_5 is a hydrocarbyl group having 1-20 carbon atoms, or a hydrocarbyl group having 1-6 carbon atoms.

[0030] Nonlimiting examples of fluorinated amide ester include

2-((4-fluorobenzamido)methyl)-3-methylbutyl	4-fluorobenzoate,	3-((4-fluorobenzamido)methyl)-4-methylpentan-2-yl
4-fluorobenzamido)methyl)-4-methylpentan-2-yl	4-fluorobenzoate,	4-((4-fluorobenzamido)methyl)-5-methylhexan-3-yl
4-fluorobenzamido)methyl)-5-methylhexan-3-yl	4-fluorobenzoate,	4-((4-fluorobenzamido)methyl)-2,5-dimethylhexan-3-yl
4-fluorobenzamido)methyl)-2,5-dimethylhexan-3-yl	4-fluorobenzoate,	4-((4-fluorobenzamido)methyl)-2,2,5-trimethylhexan-3-yl
4-fluorobenzamido)methyl)-2,2,5-trimethylhexan-3-yl	4-fluorobenzoate,	3-((4-fluorobenzamido)methyl)-2,6-dimethylheptan-4-yl
4-fluorobenzamido)methyl)-2,6-dimethylheptan-4-yl	4-fluorobenzoate,	2-((4-fluorobenzamido)methyl)-3-methyl-1-phenylbutyl
4-fluorobenzamido)methyl)-3-methyl-1-phenylbutyl	4-fluorobenzoate,	2-((4-fluorobenzamido)methyl)-4-methylpentyl
4-fluorobenzamido)methyl)-4-methylpentyl	4-fluorobenzoate,	3-((4-fluorobenzamido)methyl)-5-methylhexan-2-yl
4-fluorobenzamido)methyl)-5-methylhexan-2-yl	4-fluorobenzoate,	4-((4-fluorobenzamido)methyl)-6-methylheptan-3-yl
4-fluorobenzamido)methyl)-6-methylheptan-3-yl	4-fluorobenzoate,	4-((4-fluorobenzamido)methyl)-2,6-dimethylheptan-3-yl
4-fluorobenzamido)methyl)-2,6-dimethylheptan-3-yl	4-fluorobenzoate,	4-((4-fluorobenzamido)methyl)-2,2,6-trimethylheptan-3-yl
4-fluorobenzamido)methyl)-2,2,6-trimethylheptan-3-yl	4-fluorobenzoate,	5-((4-fluorobenzamido)methyl)-2,7-dimethyloctan-4-yl
4-fluorobenzamido)methyl)-2,7-dimethyloctan-4-yl	4-fluorobenzoate,	2-((4-fluorobenzamido)methyl)-4-methyl-1-phenylpentyl
4-fluorobenzamido)methyl)-4-methyl-1-phenylpentyl	4-fluorobenzoate,	2-((4-fluorobenzamido)methyl)-4-methyl-1-phenylpentyl

fluorobenzamido)methyl)-3,3-dimethylbutyl 4-fluorobenzoate, 3-((4-
 fluorobenzamido)methyl)-4,4-dimethylpentan-2-yl 4-fluorobenzoate, 4-((4-
 fluorobenzamido)methyl)-5,5-dimethylhexan-3-yl 4-fluorobenzoate, 4-((4-
 fluorobenzamido)methyl)-2,5,5-trimethylhexan-3-yl 4-fluorobenzoate, 4-((4-
 fluorobenzamido)methyl)-2,2,5,5-tetramethylhexan-3-yl 4-fluorobenzoate, 3-((4-
 fluorobenzamido)methyl)-2,2,6-trimethylheptan-4-yl 4-fluorobenzoate, 2-((4-
 fluorobenzamido)methyl)-3,3-dimethyl-1-phenylbutyl 4-fluorobenzoate, 3-(4-
 fluorobenzamido)-2-phenylpropyl 4-fluorobenzoate, 4-(4-fluorobenzamido)-3-phenylbutan-
 2-yl 4-fluorobenzoate, 1-(4-fluorobenzamido)-2-phenylpentan-3-yl 4-fluorobenzoate, 1-(4-
 fluorobenzamido)-4-methyl-2-phenylpentan-3-yl 4-fluorobenzoate, 1-(4-fluorobenzamido)-
 4,4-dimethyl-2-phenylpentan-3-yl 4-fluorobenzoate, 1-(4-fluorobenzamido)-5-methyl-2-
 phenylhexan-3-yl 4-fluorobenzoate, 3-(4-fluorobenzamido)-1,2-diphenylpropyl 4-
 fluorobenzoate, 3-((4-fluorobenzamido)methyl)-3-isopropyl-5-methylhexan-2-yl 4-
 fluorobenzoate, 4-((4-fluorobenzamido)methyl)-4-isopropyl-6-methylheptan-3-yl 4-
 fluorobenzoate, 4-((4-fluorobenzamido)methyl)-4-isopropyl-2,6-dimethylheptan-3-yl 4-
 fluorobenzoate, 4-((4-fluorobenzamido)methyl)-4-isopropyl-2,2,6-trimethylheptan-3-yl 4-
 fluorobenzoate, 5-((4-fluorobenzamido)methyl)-5-isopropyl-2,7-dimethyloctan-4-yl 4-
 fluorobenzoate, 2-((4-fluorobenzamido)methyl)-2-isopropyl-4-methyl-1-phenylpentyl 4-
 fluorobenzoate, 3-((4-fluorobenzamido)methyl)-3-isopropyl-4-methylpentan-2-yl 4-
 fluorobenzoate, 4-((4-fluorobenzamido)methyl)-4-isopropyl-5-methylhexan-3-yl 4-
 fluorobenzoate, 4-((4-fluorobenzamido)methyl)-4-isopropyl-2,5-dimethylhexan-3-yl 4-
 fluorobenzoate, 4-((4-fluorobenzamido)methyl)-4-isopropyl-2,2,5-trimethylhexan-3-yl 4-
 fluorobenzoate, 3-((4-fluorobenzamido)methyl)-3-isopropyl-2,6-dimethylheptan-4-yl 4-
 fluorobenzoate, 2-((4-fluorobenzamido)methyl)-2-isopropyl-3-methyl-1-phenylbutyl 4-
 fluorobenzoate, 3-((4-fluorobenzamido)methyl)-3-isobutyl-5-methylhexan-2-yl 4-
 fluorobenzoate, 4-((4-fluorobenzamido)methyl)-4-isobutyl-6-methylheptan-3-yl 4-
 fluorobenzoate, 4-((4-fluorobenzamido)methyl)-4-isobutyl-2,6-dimethylheptan-3-yl 4-
 fluorobenzoate, 4-((4-fluorobenzamido)methyl)-4-isobutyl-2,2,6-trimethylheptan-3-yl 4-
 fluorobenzoate, 5-((4-fluorobenzamido)methyl)-5-isobutyl-2,7-dimethyloctan-4-yl 4-
 fluorobenzoate, 4-(4-fluorobenzamido)pentan-2-yl 4-fluorobenzoate, and 2-((4-
 fluorobenzamido)methyl)-2-isobutyl-4-methyl-1-phenylpentyl 4-fluorobenzoate.

[0031] Nonlimiting examples of chlorinated amide ester include 2-((4-chlorobenzamido)methyl)-3-methylbutyl 4-chlorobenzoate, 3-((4-chlorobenzamido)methyl)-4-methylpentan-2-yl 4-chlorobenzoate, 4-((4-chlorobenzamido)methyl)-5-methylhexan-3-yl 4-chlorobenzoate, 4-((4-chlorobenzamido)methyl)-2,5-dimethylhexan-3-yl 4-chlorobenzoate, 4-((4-chlorobenzamido)methyl)-2,2,5-trimethylhexan-3-yl 4-chlorobenzoate, 3-((4-chlorobenzamido)methyl)-2,6-dimethylheptan-4-yl 4-chlorobenzoate, 2-((4-chlorobenzamido)methyl)-3-methyl-1-phenylbutyl 4-chlorobenzoate, 2-((4-chlorobenzamido)methyl)-4-methylpentyl 4-chlorobenzoate, 3-((4-chlorobenzamido)methyl)-5-methylhexan-2-yl 4-chlorobenzoate, 4-((4-chlorobenzamido)methyl)-6-methylheptan-3-yl 4-chlorobenzoate, 4-((4-chlorobenzamido)methyl)-2,6-dimethylheptan-3-yl 4-chlorobenzoate, 4-((4-chlorobenzamido)methyl)-2,2,6-trimethylheptan-3-yl 4-chlorobenzoate, 5-((4-chlorobenzamido)methyl)-2,7-dimethyloctan-4-yl 4-chlorobenzoate, 2-((4-chlorobenzamido)methyl)-4-methyl-1-phenylpentyl 4-chlorobenzoate, 2-((4-chlorobenzamido)methyl)-3,3-dimethylbutyl 4-chlorobenzoate, 3-((4-chlorobenzamido)methyl)-4,4-dimethylpentan-2-yl 4-chlorobenzoate, 4-((4-chlorobenzamido)methyl)-5,5-dimethylhexan-3-yl 4-chlorobenzoate, 4-((4-chlorobenzamido)methyl)-2,5,5-trimethylhexan-3-yl 4-chlorobenzoate, 4-((4-chlorobenzamido)methyl)-2,2,5,5-tetramethylhexan-3-yl 4-chlorobenzoate, 3-((4-chlorobenzamido)methyl)-2,2,6-trimethylheptan-4-yl 4-chlorobenzoate, 2-((4-chlorobenzamido)methyl)-3,3-dimethyl-1-phenylbutyl 4-chlorobenzoate, 3-((4-chlorobenzamido)-2-phenylpropyl 4-chlorobenzoate, 4-((4-chlorobenzamido)-3-phenylbutan-2-yl 4-chlorobenzoate, 1-((4-chlorobenzamido)-2-phenylpentan-3-yl 4-chlorobenzoate, 1-((4-chlorobenzamido)-4-methyl-2-phenylpentan-3-yl 4-chlorobenzoate, 1-((4-chlorobenzamido)-4,4-dimethyl-2-phenylpentan-3-yl 4-chlorobenzoate, 1-((4-chlorobenzamido)-5-methyl-2-phenylhexan-3-yl 4-chlorobenzoate, 3-((4-chlorobenzamido)-1,2-diphenylpropyl 4-chlorobenzoate, 3-((4-chlorobenzamido)methyl)-3-isopropyl-5-methylhexan-2-yl 4-chlorobenzoate, 4-((4-chlorobenzamido)methyl)-4-isopropyl-6-methylheptan-3-yl 4-chlorobenzoate, 4-((4-chlorobenzamido)methyl)-4-isopropyl-2,6-dimethylheptan-3-yl 4-chlorobenzoate, 4-((4-chlorobenzamido)methyl)-4-isopropyl-2,2,6-trimethylheptan-3-yl 4-chlorobenzoate, 5-((4-chlorobenzamido)methyl)-5-isopropyl-2,7-dimethyloctan-4-yl 4-

chlorobenzoate, 2-((4-chlorobenzamido)methyl)-2-isopropyl-4-methyl-1-phenylpentyl 4-chlorobenzoate, 3-((4-chlorobenzamido)methyl)-3-isopropyl-4-methylpentan-2-yl 4-chlorobenzoate, 4-((4-chlorobenzamido)methyl)-4-isopropyl-5-methylhexan-3-yl 4-chlorobenzoate, 4-((4-chlorobenzamido)methyl)-4-isopropyl-2,5-dimethylhexan-3-yl 4-chlorobenzoate, 4-((4-chlorobenzamido)methyl)-4-isopropyl-2,2,5-trimethylhexan-3-yl 4-chlorobenzoate, 3-((4-chlorobenzamido)methyl)-3-isopropyl-2,6-dimethylheptan-4-yl 4-chlorobenzoate, 2-((4-chlorobenzamido)methyl)-2-isopropyl-3-methyl-1-phenylbutyl 4-chlorobenzoate, 3-((4-chlorobenzamido)methyl)-3-isobutyl-5-methylhexan-2-yl 4-chlorobenzoate, 4-((4-chlorobenzamido)methyl)-4-isobutyl-6-methylheptan-3-yl 4-chlorobenzoate, 4-((4-chlorobenzamido)methyl)-4-isobutyl-2,6-dimethylheptan-3-yl 4-chlorobenzoate, 4-((4-chlorobenzamido)methyl)-4-isobutyl-2,2,6-trimethylheptan-3-yl 4-chlorobenzoate, 5-((4-chlorobenzamido)methyl)-5-isobutyl-2,7-dimethyloctan-4-yl 4-chlorobenzoate, 4-(4-chlorobenzamido)pentan-2-yl 4-chlorobenzoate, and 2-((4-chlorobenzamido)methyl)-2-isobutyl-4-methyl-1-phenylpentyl 4-chlorobenzoate.

[0032] In an embodiment, each of R_{12} and R_{22} of structure (II) is fluorine and each of R_3 and R_5 is a methyl group.

[0033] In an embodiment, each of R_{12} and R_{22} of structure (II) is fluorine and each of R_1 and R_2 is a methyl group.

[0034] In an embodiment, each of R_{12} and R_{22} of structure (II) is fluorine and each of R_1 and R_2 is an isopropyl group.

[0035] In an embodiment, each of R_{12} and R_{22} of structure (II) is fluorine and each of R_1 and R_2 is an isobutyl group.

[0036] In an embodiment, each of R_{12} and R_{22} of structure (II) is fluorine, R_1 is an isopropyl group, and R_2 is an isobutyl group.

[0037] In an embodiment, each of R_{12} and R_{22} of structure (II) is chlorine and each of R_3 and R_5 is a methyl group.

[0038] In an embodiment, each of R_{12} and R_{22} is chlorine and each of R_1 and R_2 is a methyl group.

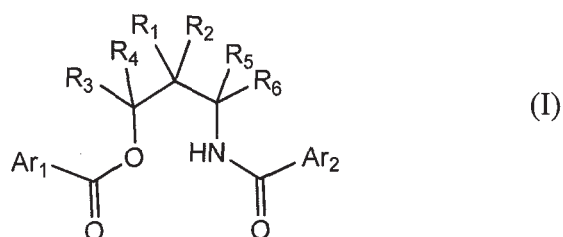
[0039] In an embodiment, each of R_{12} and R_{22} is chlorine and each of R_1 and R_2 is an isopropyl group.

[0040] In an embodiment, each of R_{12} and R_{22} is chlorine and each of R_1 and R_2 is an isobutyl group.

[0041] In an embodiment, each of R_{12} and R_{22} of structure (II) is chlorine, R_1 is an isopropyl group, and R_2 is an isobutyl group.

[0042] The present halogenated amide ester may comprise two or more embodiments enclosed herein.

[0043] In an embodiment, a procatalyst composition is provided. The procatalyst composition includes a combination of a magnesium moiety, a titanium moiety and an internal electron donor. In other words, the procatalyst composition is a reaction product of a procatalyst precursor, a halogenated amide ester, an optional halogenating agent, and an optional titanating agent. The internal electron donor includes a halogenated amide ester of structure (I):



[0044] wherein R_1 - R_6 are the same or different. Each of R_1 - R_6 is selected from hydrogen, a halogen, and a substituted/unsubstituted hydrocarbyl group having 1-20 atoms. Ar_1 and Ar_2 are the same or different. Each of Ar_1 and Ar_2 is selected from an aryl group having 6-20 atoms and an arylalkyl group having 7-20 carbon atoms. At least one of Ar_1 and Ar_2 is halogenated.

[0045] Two or more of the R_1 - R_6 may link to form a cyclic or poly-cyclic structure as previously discussed. Ar_1 and Ar_2 may be any compound or structure as previously discussed. The internal electron donor may be any of the foregoing halogenated amide esters.

[0046] The procatalyst composition is produced by halogenating/titanating a procatalyst precursor in the presence of the internal electron donor. As used herein, an "internal electron donor" is a compound added or otherwise formed during formation of the procatalyst composition that donates at least one pair of electrons to one or more metals present in the resultant procatalyst composition. The internal electron donor is the halogenated amide ester.

Not wishing to be bound by any particular theory, it is believed that during halogenation and titanation the internal electron donor (1) regulates the formation of active sites, (2) regulates the position of titanium on the magnesium-based support and thereby enhances catalyst stereoselectivity, (3) facilitates conversion of the magnesium and titanium moieties into respective halides and (4) regulates the crystallite size of the magnesium halide support during conversion. Thus, provision of the internal electron donor yields a procatalyst composition with enhanced stereoselectivity.

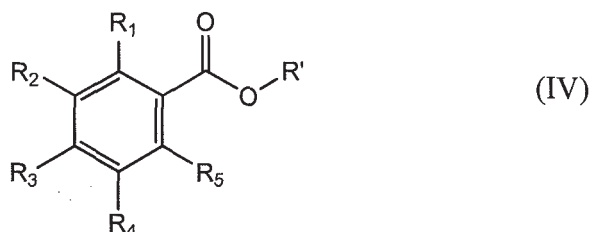
[0047] The procatalyst precursor may be a magnesium moiety compound (MagMo), a magnesium mixed metal compound (MagMix), or a benzoate-containing magnesium chloride compound (BenMag). In an embodiment, the procatalyst precursor is a magnesium moiety ("MagMo") precursor. The "MagMo precursor" contains magnesium as the sole metal component. The MagMo precursor includes a magnesium moiety. Nonlimiting examples of suitable magnesium moieties include anhydrous magnesium chloride and/or its alcohol adduct, magnesium alkoxide or aryloxide, mixed magnesium alkoxy halide, and/or carbonated magnesium dialkoxide or aryloxide. In one embodiment, the MagMo precursor is a magnesium di-(C₁₋₄)alkoxide. In a further embodiment, the MagMo precursor is diethoxymagnesium.

[0048] The MagMix includes magnesium and at least one other metal atom. The other metal atom can be a main group metal or a transition metal, or a transition metal of IIIB – VIIIB element. In an embodiment, the transition metal is selected from Sc, Ti, V, Cr, Mn, Fe, Co, Ni, Y, Zr, Nb, and Hf. In a further embodiment, the MagMix precursor is a mixed magnesium/titanium compound ("MagTi"). The "MagTi precursor" has the formula $Mg_dTi(OR^e)_fX_g$ wherein R^e is an aliphatic or aromatic hydrocarbon radical having 1 to 14 carbon atoms or COR' wherein R' is an aliphatic or aromatic hydrocarbon radical having 1 to 14 carbon atoms; each OR^e group is the same or different; X is independently chlorine, bromine or iodine, preferably chlorine; d is 0.5 to 56, or 2 to 4; f is 2 to 116 or 5 to 15; and g is 0.5 to 116, or 1 to 3.

[0049] In an embodiment, the procatalyst precursor is a benzoate-containing magnesium chloride material. As used herein, a "benzoate-containing magnesium chloride" ("BenMag") is a magnesium chloride procatalyst (*i.e.*, a halogenated procatalyst precursor) containing a benzoate internal electron donor. The BenMag material may also include a titanium moiety,

such as a titanium halide. The benzoate internal donor is labile and can be replaced by other electron donors during procatalyst synthesis. Nonlimiting examples of suitable benzoate groups include ethyl benzoate, methyl benzoate, ethyl p-methoxybenzoate, methyl p-ethoxybenzoate, ethyl p-ethoxybenzoate, ethyl p-chlorobenzoate. In one embodiment, the benzoate group is ethyl benzoate. Nonlimiting examples of suitable BenMag procatalyst precursors include catalysts of the trade names SHACTM 103 and SHACTM 310 available from The Dow Chemical Company, Midland, Michigan.

[0050] In an embodiment, the BenMag procatalyst precursor is a product of halogenation of any procatalyst precursor (*i.e.*, a MagMo precursor or a MagTi precursor) in the presence of a benzoate compound with the structure (IV)



[0051] wherein $R_1 - R_5$ are H, a $C_1 - C_{20}$ hydrocarbyl group which may contain heteroatoms including F, Cl, Br, I, O, S, N, P, and Si, and R' is a $C_1 - C_{20}$ hydrocarbyl group which may optionally contain heteroatom(s) including F, Cl, Br, I, O, S, N, P, and Si. Preferably, $R_1 - R_5$ are selected from H and a $C_1 - C_{20}$ alkyl group and R' is selected from a $C_1 - C_{20}$ alkyl group and an alkoxyalkyl group.

[0052] Halogenation/titanation of the procatalyst precursor in the presence of the internal electron donor produces a procatalyst composition which includes a combination of a magnesium moiety, a titanium moiety, and the internal electron donor (a halogenated amide ester). In an embodiment, the magnesium and titanium moieties are respective halides, such as magnesium chloride and titanium chloride. Bounded by no particular theory, it is believed that the magnesium halide is a support upon which the titanium halide is deposited and onto which the internal electron donor is incorporated.

[0053] The resulting procatalyst composition has a titanium content of from about 1.0 percent by weight to about 6.0 percent by weight, based on the total solids weight, or from about 1.5 percent by weight to about 5.5 percent by weight, or from about 2.0 percent by weight to about 5.0 percent by weight. The weight ratio of titanium to magnesium in the

solid procatalyst composition is suitably between about 1:3 and about 1:160, or between about 1:4 and about 1:50, or between about 1:6 and 1:30. The internal electron donor is present in an amount from about 0.1 wt % to about 20.0 wt %, or from about 1.0 wt % to about 15 wt %. The internal electron donor may be present in the procatalyst composition in a molar ratio of internal electron donor to magnesium of from about 0.005:1 to about 1:1, or from about 0.01:1 to about 0.4:1. Weight percent is based on the total weight of the procatalyst composition.

[0054] Ethoxide content in the procatalyst composition indicates the completeness of conversion of precursor metal ethoxide into a metal halide. The halogenated amide ester assists in converting ethoxide into halide during halogenation. In an embodiment, the procatalyst composition includes from about 0.01 wt % to about 1.0 wt %, or from about 0.05 wt % to about 0.5 wt % ethoxide. Weight percent is based on the total weight of the procatalyst composition.

[0055] In an embodiment, the internal electron donor is a mixed internal electron donor. As used herein, a “mixed internal electron donor” is (i) a halogenated amide ester, (ii) an electron donor component that donates a pair of electrons to one or more metals present in the resultant procatalyst composition, and (iii) optionally other components. In an embodiment, the electron donor component is a benzoate, such as ethyl benzoate and/or methoxypropan-2-yl benzoate. The procatalyst composition with the mixed internal electron donor can be produced by way of the procatalyst production procedure as previously disclosed.

[0056] In an embodiment, the internal electron donor and/or the mixed internal electron donor are/is phthalate-free.

[0057] In an embodiment, the procatalyst composition is phthalate-free.

[0058] The present procatalyst composition may comprise two or more embodiments disclosed herein.

[0059] In an embodiment, a catalyst composition is provided. As used herein, “a catalyst composition” is a composition that forms an olefin-based polymer when contacted with an olefin under polymerization conditions. The catalyst composition includes a procatalyst composition and a cocatalyst. The procatalyst composition can be any of the foregoing procatalyst compositions with an internal electron donor that is a halogenated amide ester of

structure (I) or structure (II) as disclosed herein. The catalyst composition may optionally include an external electron donor and/or an activity limiting agent.

[0060] In an embodiment, the internal electron donor of the catalyst composition is a mixed internal electron donor as disclosed above.

[0061] The catalyst composition includes a cocatalyst. As used herein, a “cocatalyst” is a substance capable of converting the procatalyst to an active polymerization catalyst. The cocatalyst may include hydrides, alkyls, or aryls of aluminum, lithium, zinc, tin, cadmium, beryllium, magnesium, and combinations thereof. In an embodiment, the cocatalyst is a hydrocarbyl aluminum compound represented by the formula R_nAlX_{3-n} wherein $n = 1, 2, \text{ or } 3$, R is an alkyl, and X is a halide or alkoxide. Nonlimiting examples of suitable cocatalyst include trimethylaluminum, triethylaluminum, triisobutylaluminum, and tri-n-hexylaluminum.

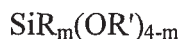
[0062] In an embodiment, the cocatalyst is triethylaluminum. The molar ratio of aluminum to titanium is from about 5:1 to about 500:1, or from about 10:1 to about 200:1, or from about 15:1 to about 150:1, or from about 20:1 to about 100:1, or from about 30:1 to about 60:1. In another embodiment, the molar ratio of aluminum to titanium is about 35:1.

[0063] In an embodiment, the present catalyst composition includes an external electron donor. As used herein, an “external electron donor” (or “EED”) is a compound added independent of procatalyst formation and includes at least one functional group that is capable of donating a pair of electrons to a metal atom. A “mixed external electron donor” (or “MEED”) is a mixture of two or more external electron donors. Bounded by no particular theory, it is believed that provision of one or more external electron donors in the catalyst composition effects the following properties of the formant polymer: level of tacticity (*i.e.*, xylene soluble material), molecular weight (*i.e.*, melt flow), molecular weight distribution (MWD), melting point, and/or oligomer level.

[0064] In an embodiment, the external electron donor may be selected from one or more of the following: a silicon compound, a bidentate compound, an amine, an ether, a carboxylate, a ketone, an amide, a carbamate, a phosphine, a phosphate, a phosphite, a sulfonate, a sulfone, a sulfoxide, and any combination of the foregoing.

[0065] In an embodiment, the EED is a silicon compound having the general formula (III):

(III)



wherein R independently each occurrence is hydrogen or a hydrocarbyl or an amino group, optionally substituted with one or more substituents containing one or more Group 14, 15, 16, or 17 heteroatoms. R contains up to 20 atoms not counting hydrogen and halogen. R' is a C₁₋₂₀ alkyl group, and m is 0, 1, or 2. In an embodiment, R is C₆₋₁₂ aryl, alkylaryl or aralkyl, C₃₋₁₂ cycloalkyl, C₁₋₂₀ linear alkyl or alkenyl, C₃₋₁₂ branched alkyl, or C₂₋₁₂ cyclic amino group, R' is C₁₋₄ alkyl, and m is 1 or 2.

[0066] Nonlimiting examples of suitable silicon compounds for the EED include dialkoxysilanes, trialkoxysilanes, and tetraalkoxysilanes such as dicyclopentyl dimethoxysilane, diisopropyl dimethoxysilane (DCPDMS), bis(perhydroisoquinolino) dimethoxysilane, methylcyclohexyl dimethoxysilane, tetraethoxysilane, n-propyl trimethoxysilane, n-propyl triethoxysilane, diethylaminotriethoxysilane, bis(trimethylsilylmethyl) dimethoxysilane, and any combination thereof.

[0067] In an embodiment, the EED is a bidentate compound. A “bidentate compound” is a molecule or compound that contains at least two oxygen-containing functional groups separated by a C₂-C₁₀ hydrocarbon chain, the oxygen-containing functional groups being the same or different and at least one oxygen-containing functional group being an ether group or a carboxylate group, the bidentate composition excluding phthalates. Nonlimiting examples of suitable oxygen-containing functional groups for the bidentate composition include carboxylate, carbonate, ketone, ether, carbamate, amide, sulfoxide, sulfone, sulfonate, phosphite, phosphinate, phosphate, phosphonate, and phosphine oxide. One or more carbon atoms in the C₂ - C₁₀ chain may be substituted with heteroatoms from Group 14, 15, and 16. One or more H atoms in the C₂ - C₁₀ chain may be substituted with alkyl, cycloalkyl, alkenyl, cycloalkenyl, aryl, alkylaryl, aralkyl, halogen, or functional groups containing a heteroatom from Group 14, 15, or 16. Nonlimiting examples of suitable bidentate compounds include diethers, succinates, dialkoxybenzenes, alkoxy ester, and/or diol esters.

[0068] In an embodiment, the bidentate compound is a diether such as 3,3-bis(methoxymethyl)-2,5-dimethylhexane, 4,4-bis(methoxymethyl)-2,6-dimethylheptane, and 9,9-bis(methoxymethyl)fluorene.

[0069] In an embodiment, the bidentate compound is a diol ester such as 2,4-pentanediol di(benzoate), 2,4-pentanediol di(2-methylbenzoate), 2,4-pentanediol di(4-n-butylbenzoate), 2,2,4-trimethyl-1,3-pentanediol diisobutyrate and/or 2,2,4-trimethyl-1,3-pentanediol dibenzoate.

[0070] In an embodiment, the carboxylate is a benzoate such as ethyl benzoate and ethyl 4-ethoxybenzoate.

[0071] In an embodiment the external electron donor is a phosphite such as trimethyl phosphate, triethyl phosphate, and/or tri-n-propyl phosphite.

[0072] In an embodiment, the external electron donor is an alkoxy ester such as methyl 1-methoxybicyclo[2.2.1]-hept-5-ene-2-carboxylate, methyl 3-methoxypropionate, methyl 3-methoxy-2-methylpropanoate, and/or ethyl 3-methoxy-2-methylpropanoate.

[0073] In an embodiment, the external electron donor is a succinate such as diethyl 2,3-diisopropylsuccinate, di-n-butyl 2,3-diisopropylsuccinate, and/or diethyl 2,3-diisobutylsuccinate.

[0074] In an embodiment, the external electron donor is a dialkoxybenzene such as 1,2-diethoxybenzene, 1,2-di-n-butoxybenzene, and/or 1-ethoxy-2-n-pentoxybenzene.

[0075] In an embodiment, the external electron donor is an amine such as 2,2,6,6-tetramethylpiperidine.

[0076] It is further understood that the EED may be a MEED which may comprise two or more of any of the foregoing EED compounds.

[0077] In an embodiment, the catalyst composition includes an activity limiting agent (ALA). As used herein, an "activity limiting agent" ("ALA") is a material that reduces catalyst activity at elevated temperature (*i.e.*, temperature greater than about 85°C). An ALA inhibits or otherwise prevents polymerization reactor upset and ensures continuity of the polymerization process. Typically, the activity of Ziegler-Natta catalysts increases as the reactor temperature rises. Ziegler-Natta catalysts also typically maintain high activity near the softening point temperature of the polymer produced. The heat generated by the exothermic polymerization reaction may cause polymer particles to form agglomerates and

may ultimately lead to disruption of continuity for the polymer production process. The ALA reduces catalyst activity at elevated temperature, thereby preventing reactor upset, reducing (or preventing) particle agglomeration, and ensuring continuity of the polymerization process.

[0078] The ALA may or may not be a component of the EED and/or the MEED. The activity limiting agent may be a carboxylic acid ester, a diether, a poly(alkene glycol), a succinate, a diol ester, and combinations thereof. The carboxylic acid ester can be an aliphatic or aromatic, mono- or poly-carboxylic acid ester. Nonlimiting examples of suitable carboxylic acid esters include benzoates, C₁₋₄₀ alkyl esters of aliphatic C₂₋₄₀ mono-/di-carboxylic acids, C₂₋₄₀ mono-/poly-carboxylate derivatives of C₂₋₁₀₀ (poly)glycols, C₂₋₁₀₀ (poly)glycol ethers, and any combination thereof. Further nonlimiting examples of carboxylic acid esters include laurates, myristates, palmitates, stearates, oleates, and sebacates, and mixtures thereof. In a further embodiment, the ALA is ethyl 4-ethoxybenzoate or isopropyl myristate or di-n-butyl sebacate.

[0079] The catalyst composition may include any of the foregoing external electron donors in combination with any of the foregoing activity limiting agents. The external electron donor and/or activity limiting agent can be added into the reactor separately. Alternatively, the external electron donor and the activity limiting agent can be mixed together in advance and then added to the catalyst composition and/or into the reactor as a mixture. In the mixture, more than one external electron donor or more than one activity limiting agent can be used. Nonlimiting examples of suitable EED/ALA mixtures include dicyclopentyl dimethoxysilane and isopropyl myristate, dicyclopentyl dimethoxysilane and poly(ethylene glycol) laurate, diisopropyl dimethoxysilane and isopropyl myristate, methylcyclohexyl dimethoxysilane and isopropyl myristate, methylcyclohexyl dimethoxysilane and ethyl 4-ethoxybenzoate, n-propyltrimethoxysilane and isopropyl myristate, dimethyldimethoxysilane and methylcyclohexyl dimethoxysilane and isopropyl myristate, dicyclopentyl dimethoxysilane and tetraethoxysilane and isopropyl myristate, dicyclopentyl dimethoxysilane and tetraethoxysilane and ethyl 4-ethoxybenzoate, dicyclopentyl dimethoxysilane and n-propyltriethoxysilane and isopropyl myristate, diisopropyl dimethoxysilane and n-propyltriethoxysilane and isopropyl myristate, dicyclopentyl dimethoxysilane and isopropyl myristate and poly(ethylene glycol) dioleate,

dicyclopentyldimethoxysilane and diisopropyldimethoxysilane and n-propyltriethoxysilane and isopropyl myristate, and combinations thereof.

[0080] The present catalyst composition may comprise two or more embodiments disclosed herein.

[0081] In an embodiment, a process for producing an olefin-based polymer is provided. The process includes contacting an olefin with a catalyst composition under polymerization conditions. The catalyst composition includes a halogenated amide ester. The halogenated amide ester can be any halogenated amide ester as disclosed herein. The process further includes forming an olefin-based polymer.

[0082] The catalyst composition includes a procatalyst composition and a cocatalyst. The procatalyst composition is any procatalyst composition disclosed herein and includes a halogenated amide ester of structure (I) or structure (II) as the internal electron donor. The cocatalyst may be any cocatalyst as disclosed herein. The catalyst composition may optionally include an external electron donor and/or an activity limiting agent as previously disclosed.

[0083] The olefin-based polymer contains halogenated amide ester corresponding to the internal electron donor of structure (I) or structure (II) present in the procatalyst composition. In an embodiment, the olefin-based polymer can be a propylene-based olefin, an ethylene-based olefin, and combinations thereof. In an embodiment, the olefin-based polymer is a propylene-based polymer.

[0084] One or more olefin monomers can be introduced into a polymerization reactor to react with the catalyst and to form a polymer, or a fluidized bed of polymer particles. Nonlimiting examples of suitable olefin monomers include ethylene, propylene, C₄₋₂₀ α -olefins, such as 1-butene, 1-pentene, 1-hexene, 4-methyl-1-pentene, 1-heptene, 1-octene, 1-decene, 1-dodecene and the like.

[0085] As used herein, "polymerization conditions" are temperature and pressure parameters within a polymerization reactor suitable for promoting polymerization between the catalyst composition and an olefin to form the desired polymer. The polymerization process may be a gas phase, a slurry, or a bulk polymerization process, operating in one, or more than one, polymerization reactor. Accordingly, the polymerization reactor may be a

gas phase polymerization reactor, a liquid-phase polymerization reactor, or a combination thereof.

[0086] It is understood that provision of hydrogen in the polymerization reactor is a component of the polymerization conditions. During polymerization, hydrogen is a chain transfer agent and affects the molecular weight (and correspondingly the melt flow rate) of the resultant polymer. The polymerization process may include a pre-polymerization step and/or a pre-activation step.

[0087] In an embodiment, the process includes mixing the external electron donor (and optionally the activity limiting agent) with the procatalyst composition. The external electron donor and/or the activity limiting agent can be complexed with the cocatalyst and mixed with the procatalyst composition (pre-mix) prior to contact between the catalyst composition and the olefin. In another embodiment, the external electron donor and/or the activity limiting agent can be added independently to the polymerization reactor.

[0088] In an embodiment, the olefin is propylene and optionally ethylene and/or 1-butene. The process includes forming a propylene-based polymer (propylene homopolymer or propylene copolymer) having one or more of the following properties:

- a melt flow rate (MFR) from about 0.01 g/10 min to about 800 g/10 min, or from about 0.1 g/10 min to about 200 g/10 min, or from about 0.5 g/10 min to about 150 g/10 min, or from about 1 g/10 min to about 70 g/10 min;
- a xylene solubles content from about 0.5% to about 10%, or from about 1% to about 8%, or from about 1% to about 4%;
- a polydispersity index (PDI) from about 5.0 to about 20.0, or from about 6.0 to about 15, or from about 6.5 to about 10, or from about 7.0 to about 9.0;
- when a comonomer is present it is present in an amount from about 0.001 wt% to about 20 wt%, or from about 0.01 wt % to about 15 wt%, or from about 0.1 wt % to about 10 wt % (based on total weight of the polymer); and/or
- internal electron donor (halogenated amide ester) or mixed internal electron donor (halogenated amide ester and a benzoate) present from about 1 ppb to about 50 ppm, or from about 10 ppb to about 25 ppm, or from about 100 ppb to about 10 ppm.

[0089] The present disclosure provides another process for producing an olefin-based polymer. In an embodiment, a process for producing an olefin-based polymer is provided which includes contacting propylene with a catalyst composition comprising a halogenated amide ester to form a propylene-based polymer. The contact between the propylene and the

catalyst composition occurs in a first polymerization reactor under polymerization conditions. The process further includes contacting ethylene and optionally at least one other olefin in the presence of the propylene-based polymer. The contact between the ethylene, the olefin(s), and the propylene-based polymer occurs in a second polymerization reactor under polymerization conditions and forms a propylene impact copolymer.

[0090] In an embodiment, the first reactor and the second reactor operate in series whereby the effluent of the first reactor (*i.e.*, the propylene-based polymer) is charged to the second reactor. Additional olefin monomer is added to the second polymerization reactor to continue polymerization. Additional catalyst composition (and/or any combination of individual catalyst components—*i.e.*, procatalyst, cocatalyst, EED, ALA) may be added to the second polymerization reactor. The additional catalyst composition/components added to the second reactor may be the same or different than the catalyst composition/components introduced in the first reactor.

[0091] In an embodiment, the propylene-based polymer produced in the first reactor is a propylene homopolymer. The propylene homopolymer is charged to the second reactor where ethylene and propylene are contacted with each other in the presence of the propylene homopolymer. This forms a propylene impact copolymer having a propylene homopolymer continuous (or matrix) phase and a discontinuous phase (or rubber phase) selected from a propylene-based copolymer (*i.e.*, a propylene/ethylene copolymer) or an ethylene-based copolymer (*i.e.*, an ethylene/propylene copolymer). The discontinuous phase is dispersed in the continuous phase.

[0092] The propylene impact copolymer may have an Fc value from about 1 wt % to about 50 wt %, or from about 10 wt % to about 40 wt %, or from about 20 wt % to about 30 wt %. As used herein, “fraction copolymer” (“Fc”) is the weight percent of the discontinuous phase present in the heterophasic copolymer. The Fc value is based on the total weight of the propylene impact copolymer.

[0093] The propylene impact copolymer may have an Ec value from about 1 wt % to about 100 wt %, or from about 20 wt % to about 90 wt %, or from about 30 wt % to about 80 wt %, or from about 40 wt % about 60 wt %. As used herein, “ethylene content” (“Ec”) is the weight percent of ethylene present in the discontinuous phase of the propylene impact copolymer. The Ec value is based on the total weight of the discontinuous (or rubber) phase.

[0094] The present processes for production olefin-based polymer may comprise two or more embodiments disclosed herein.

[0095] DEFINITIONS

[0096] All references to the Periodic Table of the Elements herein shall refer to the Periodic Table of the Elements, published and copyrighted by CRC Press, Inc., 2003. Also, any references to a Group or Groups shall be to the Groups or Groups reflected in this Periodic Table of the Elements using the IUPAC system for numbering groups. Unless stated to the contrary, implicit from the context, or customary in the art, all parts and percents are based on weight. For purposes of United States patent practice, the contents of any patent, patent application, or publication referenced herein are hereby incorporated by reference in their entirety (or the equivalent US version thereof is so incorporated by reference), especially with respect to the disclosure of synthetic techniques, definitions (to the extent not inconsistent with any definitions provided herein) and general knowledge in the art.

[0097] Any numerical range recited herein, includes all values from the lower value to the upper value, in increments of one unit, provided that there is a separation of at least 2 units between any lower value and any higher value. As an example, if it is stated that the amount of a component, or a value of a compositional or a physical property, such as, for example, amount of a blend component, softening temperature, melt index, etc., is between 1 and 100, it is intended that all individual values, such as, 1, 2, 3, etc., and all subranges, such as, 1 to 20, 55 to 70, 197 to 100, etc., are expressly enumerated in this specification. For values which are less than one, one unit is considered to be 0.0001, 0.001, 0.01 or 0.1, as appropriate. These are only examples of what is specifically intended, and all possible combinations of numerical values between the lowest value and the highest value enumerated, are to be considered to be expressly stated in this application. In other words, any numerical range recited herein includes any value or subrange within the stated range. Numerical ranges have been recited, as discussed herein, reference melt index, melt flow rate, and other properties.

[0098] The term "alkyl," as used herein, refers to a branched or unbranched, saturated or unsaturated acyclic hydrocarbon radical. Nonlimiting examples of suitable alkyl radicals

include, for example, methyl, ethyl, n-propyl, i-propyl, n-butyl, t-butyl, i-butyl (or 2-methylpropyl), etc. The alkyls have 1 to 20 carbon atoms.

[0099] The term “aryl” or “aryl group,” as used herein, is a substituent derived from an aromatic hydrocarbon compound. An aryl group has a total of from six to twenty ring atoms, and has one or more rings which are separate or fused, and may be substituted with alkyl and/or halo groups. The aromatic ring(s) may include phenyl, naphthyl, anthracenyl, and biphenyl, among others.

[00100] The term “arylalkyl” or “arylalkyl group,” as used herein, is a compound containing both aliphatic and aromatic structures. The term “arylalkyl group” includes “aralkyl groups” (an alkyl group substituted by at least one aryl group) and/or “alkylaryl groups” (an aryl group substituted by at least one alkyl group).

[00101] The terms “blend” or “polymer blend,” as used herein, is a blend of two or more polymers. Such a blend may or may not be miscible (not phase separated at molecular level). Such a blend may or may not be phase separated. Such a blend may or may not contain one or more domain configurations, as determined from transmission electron spectroscopy, light scattering, x-ray scattering, and other methods known in the art.

[00102] The term “composition,” as used herein, includes a mixture of materials which comprise the composition, as well as reaction products and decomposition products formed from the materials of the composition.

[00103] The term “comprising,” and derivatives thereof, is not intended to exclude the presence of any additional component, step or procedure, whether or not the same is disclosed herein. In order to avoid any doubt, all compositions claimed herein through use of the term “comprising” may include any additional additive, adjuvant, or compound whether polymeric or otherwise, unless stated to the contrary. In contrast, the term, “consisting essentially of” excludes from the scope of any succeeding recitation any other component, step or procedure, excepting those that are not essential to operability. The term “consisting of” excludes any component, step or procedure not specifically delineated or listed. The term “or”, unless stated otherwise, refers to the listed members individually as well as in any combination.

[00104] The term, “ethylene-based polymer,” as used herein, is a polymer that comprises a majority weight percent polymerized ethylene monomer (based on the total weight of

polymerizable monomers), and optionally may comprise at least one polymerized comonomer.

[00105] The term "olefin-based polymer" is a polymer containing, in polymerized form, a majority weight percent of an olefin, for example ethylene or propylene, based on the total weight of the polymer. Nonlimiting examples of olefin-based polymers include ethylene-based polymers and propylene-based polymers.

[00106] The term "polymer" is a macromolecular compound prepared by polymerizing monomers of the same or different type. "Polymer" includes homopolymers, copolymers, terpolymers, interpolymers, and so on. The term "interpolymer" is a polymer prepared by the polymerization of at least two types of monomers or comonomers. It includes, but is not limited to, copolymers (which usually refers to polymers prepared from two different types of monomers or comonomers, terpolymers (which usually refers to polymers prepared from three different types of monomers or comonomers), tetrapolymers (which usually refers to polymers prepared from four different types of monomers or comonomers), and the like.

[00107] The term, "propylene-based polymer," as used herein, is a polymer that comprises a majority weight percent polymerized propylene monomer (based on the total amount of polymerizable monomers), and optionally may comprise at least one polymerized comonomer.

[00108] The term "substituted alkyl," as used herein, is an alkyl as previously defined described in which one or more hydrogen atom bound to any carbon of the alkyl is replaced by another group such as a halogen, aryl, substituted aryl, cycloalkyl, substituted cycloalkyl, heterocycloalkyl, substituted heterocycloalkyl, haloalkyl, hydroxy, amino, phosphido, alkoxy, amino, thio, nitro, silyl, and combinations thereof. Suitable substituted alkyls include, for example, benzyl, trifluoromethyl and the like.

[00109] TEST METHODS

[00110] Melt flow rate (MFR) is measured in accordance with ASTM D 1238-01 test method at 230°C with a 2.16 kg weight for propylene-based polymers.

[00111] Xylene Solubles (XS) is the weight percent of resin that stays in the solution after the resin is dissolved in hot xylene and the solution is allowed to cool to 25°C (Gravimetric XS method according to ASTM D5492-06). XS is measured according to one of the two following procedures: (1) Viscotek method: 0.4 g of polymer is dissolved in 20 ml of xylenes

with stirring at 130 °C for 30 minutes. The solution is then cooled to 25 °C and after 30 minutes the insoluble polymer fraction is filtered off. The resulting filtrate is analyzed by Flow Injection Polymer Analysis using a Viscotek ViscoGEL H-100-3078 column with THF mobile phase flowing at 1.0 ml/min. The column is coupled to a Viscotek Model 302 Triple Detector Array, with light scattering, viscometer and refractometer detectors operating at 45 °C. Instrument calibration was maintained with Viscotek PolyCAL™ polystyrene standards. (2) NMR method: XS is measured using a ¹H NMR method as described in U.S. Patent No. 5,539,309, the entire content of which is incorporated herein by reference. Both of the methods are calibrated against the gravimetric ASTM method.

[00112] Polydispersity Index (PDI) is measured by an AR-G2 rheometer which is a stress control dynamic spectrometer manufactured by TA Instruments using a method according to Zeichner GR, Patel PD (1981) "A comprehensive Study of Polypropylene Melt Rheology", Proc. of the 2nd World Congress of Chemical Eng., Montreal, Canada. An ETC oven is used to control the temperature at 180°C ± 0.1°C. Nitrogen is used to purge the inside the oven to keep the sample from degradation by oxygen and moisture. A pair of 25mm in diameter cone and plate sample holder is used. Samples are compress molded into 50mm x 100mm x 2mm plaque. Samples are then cut into 19mm square and loaded on the center of the bottom plate. The geometries of upper cone is (1) Cone angle: 5:42:20 (deg:min:sec); (2) Diameter: 25 mm; (3) Truncation gap: 149 micron. The geometry of the bottom plate is 25mm cylinder.

[00113] Testing procedure:

- (1) The cone & plate sample holder is heated in the ETC oven at 180°C for 2 hours. Then the gap is zeroed under blanket of nitrogen gas.
- (2) Cone is raised to 2.5mm and sample loaded unto the top of the bottom plate.
- (3) Start timing for 2 minutes.
- (4) The upper cone is immediately lowered to slightly rest on top of the sample by observing the normal force.
- (5) After two minutes the sample is squeezed down to 165 micron gap by lower the upper cone.
- (6) The normal force is observed. When the normal force is down to <0.05 Newton the excess sample is removed from the edge of the cone and plate sample holder by a spatula.
- (7) The upper cone is lowered again to the truncation gap which is 149 micron.
- (8) An Oscillatory Frequency Sweep test is performed under these conditions:
 - (i) Test delayed at 180°C for 5 minutes.
 - (ii) Frequencies: 628.3r/s to 0.1r/s.

- (iii) Data acquisition rate: 5 point/decade.
- (iv) Strain: 10%
- (9) When the test is completed the crossover modulus (G_c) is detected by the Rheology Advantage Data Analysis program furnished by TA Instruments.
- (10) $PDI = 100,000 \div G_c$ (in Pa units).

[00114] Final melting point (T_{MF}) is the temperature to melt the most perfect crystal in the sample and is a measure for isotacticity and inherent polymer crystallizability. The test is conducted using a TA Q100 Differential Scanning Calorimeter. A sample is heated from 0°C to 240°C at a rate of 80°C/min, cooled at the same rate to 0°C, then heated again at the same rate up to 150°C, held at 150°C for 5 minutes and the heated from 150°C to 180°C at 1.25 °C/min. The T_{MF} is determined from this last cycle by calculating the onset of the baseline at the end of the heating curve.

[00115] Testing procedure:

- (1) Calibrate instrument with high purity indium as standard.
- (2) Purge the instrument head/cell with a constant 50 ml/min flow rate of nitrogen constantly.
- (3) Sample preparation:
Compression mold 1.5 g of powder sample using a 30-G302H-18-CX Wabash Compression Molder (30 ton): (a) heat mixture at 230 °C for 2 minutes at contact; (b) compress the sample at the same temperature with 20 ton pressure for 1 minute; (c) cool the sample to 45°F and hold for 2 minutes with 20 ton pressure; (d) cut the plaque into 4 of about the same size, stack them together, and repeat steps (a) – (c) in order to homogenize sample.
- (4) Weigh a piece of sample (preferably between 5 to 8 mg) from the sample plaque and seal it in a standard aluminum sample pan. Place the sealed pan containing the sample on the sample side of the instrument head/cell and place an empty sealed pan in the reference side. If using the auto sampler, weigh out several different sample specimens and set up the machine for a sequence.
- (5) Measurements:
 - (i) Data storage: off
 - (ii) Ramp 80.00 °C/min to 240.00 °C
 - (iii) Isothermal for 1.00 min
 - (iv) Ramp 80.00 °C/min to 0.00 °C
 - (v) Isothermal for 1.00 min
 - (vi) Ramp 80.00 °C/min to 150.00 °C
 - (vii) Isothermal for 5.00 min
 - (viii) Data storage: on

- (ix) Ramp 1.25 °C/min to 180.00 °C
 (x) End of method

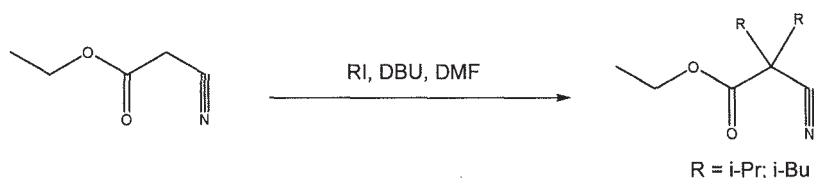
(6) Calculation: T_{MF} is determined by the interception of two lines. Draw one line from the base-line of high temperature. Draw another line from through the deflection of the curve close to the end of the curve at high temperature side.

[00116] By way of example and not by limitation, examples of the present disclosure will now be provided.

[00117] EXAMPLES

1. *Synthesis of Halogenated Amide Ester*

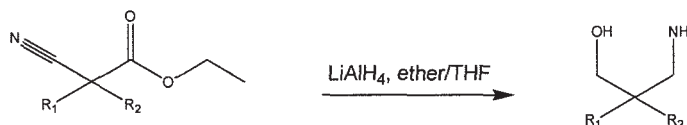
Ethyl 2-cyano-2-isobutyl-4-methylpentanoate, and ethyl 2-cyano-2-isopropyl-3-methylbutyrate:



[00118] A 500-ml round-bottom flask is fit with magnetic stirrer, and is charged with ethyl 2-cyanoacetate (11.3 g, 0.1 mol) and anhydrous DMF (120 ml). To the stirred solution a solution of 1,8-diazabicyclo[5.4.0]undec-7-ene (DBU) (30.4 g, 0.2 mol, 1.0 equiv.) in anhydrous DMF (40 ml) is added dropwise. After the completion of addition, the mixture is stirred for another hour. The flask is cooled in an ice-water bath, and a solution of the iodide (0.2 mol, 1.0 equiv.) in DMF (40 ml) is added dropwise. The mixture is raised to room temperature and stirred for another 14 hours until all starting material is converted into the product (monitored by GC). The mixture is poured into ice-water, and extracted with diethyl ether. The combined ether extract is washed with water and brine, dried over magnesium sulfate. After filtration, the filtrate concentrated, and the residue is distilled *in vacuo* to yield the product as colorless liquid.

[00119] Ethyl 2-cyano-2-isopropyl-3-methylbutyrate: Yield 67%; ^1H NMR: δ 4.24 (q, 2H, $J = 7.0$ Hz), 2.28 (heptat, 2H, $J = 7.0$ Hz) 1.30 (t, 3H, $J = 7.0$ Hz), 1.07 (d, 6H, $J = 7.0$ Hz), 1.01 (d, 6H, $J = 6.5$ Hz).

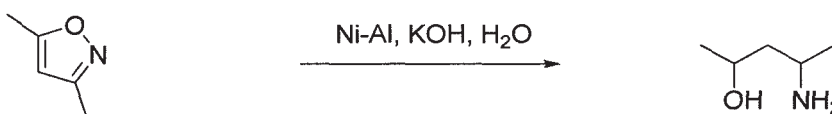
[00120] Ethyl 2-cyano-2-isobutyl-4-methylpentanoate: Yield 88%; ^1H NMR: δ 4.26 (q, 2H, $J = 7.0$ Hz), 1.82-1.90 (m, 4H), 1.63-1.70 (m, 2H), 1.34 (t, 3H, $J = 7.0$ Hz), 1.04 (d, 6H, $J = 6.0$ Hz), 0.89 (d, 6H, $J = 6.0$ Hz).

2,2-Disubstituted 3-aminopropanols:

[00121] A nitrogen purged 1000-ml three-neck round bottom flask is fit with magnetic stirrer, condenser, and dropping funnel. Powdered lithium aluminum hydride (0.14 ~ 0.18 mol) is added followed by anhydrous THF (140 ~ 180 ml), which can be replaced by commercial 1.0 M lithium aluminum hydride in THF. While stirred, a solution of the ethyl 2-cyano-2-(R₁)(R₂)carboxylate compound (0.06 ~ 0.08 mol) in ether (~200 ml) is added dropwise to keep the mixture in gentle reflux. Upon the completion of addition, the mixture is heated to gentle reflux for 3 hours. After being cooled down, the flask is put in an ice-water bath. Water is carefully added, and the mixture is stirred until the solid turned white. After filtration, the solid is washed with additional ether, the filtrate concentrated, and the residue dried *in vacuo* to yield the product as a white solid or sticky oil which can be used directly in acylation reactions without further purification.

[00122] 2-Aminomethyl-2-isopropyl-3-methylbutan-1-ol: Yield 71%; ¹H NMR: δ 3.72 (s, 2H), 2.93 (s, 2H), 2.65 (br.s, 3H), 1.97 (heptat, 2H, *J* = 8.8 Hz), 0.95 (d, 6H, *J* = 8.5 Hz), 0.94 (d, 6H, *J* = 9.0 Hz).

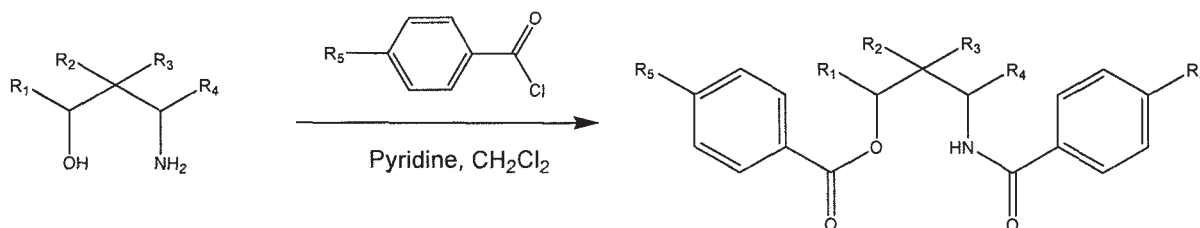
[00123] 2-Aminomethyl-2-isobutyl-4-methylpentan-1-ol: Yield 75%; ¹H NMR: δ 3.54 (s, 2H), 2.77 (s, 2H), 2.65 (br.s, 3H), 1.58-1.70 (m, 2H), 1.21 (d, 2H, *J* = 7.0 Hz), 1.20 (d, 2H, *J* = 7.5 Hz), 0.88 (d, 6H, *J* = 8.0 Hz), 0.87 (d, 6H, *J* = 8.5 Hz).

*4-Aminopentan-2-ol:*

[00124] A 1000-mL round-bottom flask is charged with 3,5-dimethylisoxazole (9.7 g, 0.1 mol) and water (200 ml). To this solution is added 1.0 M aqueous potassium hydroxide (200 mL). Nickel-aluminum alloy (1:1, 32 g, 0.2 mol) is added in portions over 1 hour. After about another two hours, the reaction mixture is filtered over celite, and the solid washed with additional water. The filtrate is extracted with methylene chloride once. The aqueous solution is acidified with concentrated HCl, and concentrated to dryness. Potassium

hydroxide (10 M, 5.0 ml) is added to the residue, the mixture is extracted with methylene chloride, and the extract is dried with magnesium sulfate. After filtration, the filtrate is concentrated, the residue is dried *in vacuo* to yield 9.0 g (87%) of the product as a sticky oil, which is used directly in the following acylation reaction. ^1H NMR (two isomers about 1 : 1.3): δ 4.10-4.18 (m, 1Ha), 3.95-4.00 (m, 1Hb), 3.37-3.41 (m, 1Ha), 3.00-3.05 (m, 1Hb), 2.63 (br.s, 3Ha+3Hb), 1.42-1.55 (m, 2Ha+1Hb), 1.12-1.24 (m, 6Ha+7Hb).

Acylated aminoalcohols:



A 250-ml round bottom flask is charged with aminoalcohol (0.02 mol), pyridine (0.04 mol, 1.0 equiv.) and methylene chloride (50 ml). The flask is immersed in an ice-water bath, and benzoyl chloride (0.04 mol, 1.0 equiv.) is added dropwise. After the completion of addition, the flask is warmed up to room temperature, and the mixture is stirred overnight. Upon the completion of reaction monitored by GC, the mixture is diluted with methylene chloride, and washed with water, saturated ammonium chloride, water, saturated sodium bicarbonate, and brine, consequently. The solution is dried over magnesium sulfate, filtered, and the filtrate concentrated. The residue is purified by flash column chromatography to yield the product as a colorless oil or white solid.

[00125] ^1H NMR data is obtained on a Brüker 500 MHz or 400 MHz NMR spectrometer using CDCl₃ as solvent (in ppm).

[00126] Amide esters produced by the foregoing synthesis are provided in Table 1 below.

Table 1
Halogenated Amide Esters

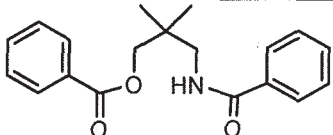
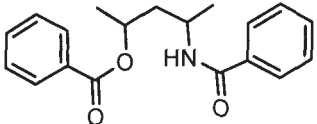
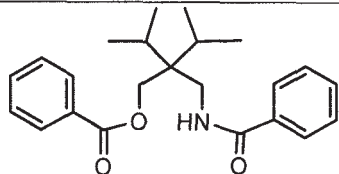
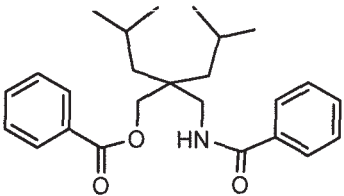
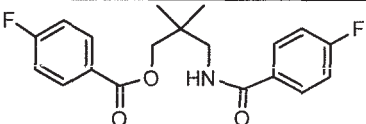
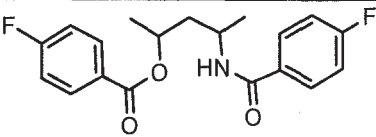
Compound	Structure	¹ H NMR (CDCl ₃ as solvent (in ppm))
(1) 3-benzamido-2,2-dimethylpropyl benzoate		Yield 88%; δ 8.08 (d, 2H, <i>J</i> = 8.5 Hz), 8.85 (d, 2H, <i>J</i> = 8.0 Hz), 7.32-7.62 (m, 6H), 6.99 (t, 1H, <i>J</i> = 6.5 Hz), 4.23 (s, 2H), 3.38 (d, 2H, <i>J</i> = 6.5 Hz), 1.10 (s, 6H).
(2) 4-benzamidopentan-2-yl benzoate		Yield 71% (two isomers with a ratio about 2.1 to 1); isomer 1: δ 7.96 (dd, 2H, <i>J</i> = 10.5, 2.0 Hz), 7.68 (dd, 2H, <i>J</i> = 10.5, 1.5 Hz), 7.24-7.52 (m, 6H), 6.67 (m, 1H), 5.25-5.34 (m, 1H), 4.27-4.38 (m, 1H), 1.90-2.02 (m, 2H), 1.35 (d, 3H, <i>J</i> = 7.5 Hz), 1.27 (d, 3H, <i>J</i> = 7.5 Hz); isomer 2: δ 8.05 (dd, 2H, <i>J</i> = 10.5, 2.0 Hz), 7.81 (dd, 2H, <i>J</i> = 10.0, 2.0 Hz), 7.39-7.56 (m, 6H), 6.40 (d, 1H, <i>J</i> = 9.5 Hz), 5.22 (qt, 1H, <i>J</i> = 7.5, 8.0 Hz), 4.28-4.40 (m, 1H), 2.12 (ddd, 1H, <i>J</i> = 7.5, 11.0, 17.5 Hz), 1.81 (ddd, 1H, <i>J</i> = 7.0, 8.5, 17.5 Hz), 1.44 (d, 3H, <i>J</i> = 8.0 Hz), 1.29 (d, 3H, <i>J</i> = 8.5 Hz).
(3) 2-(benzamidomethyl)-2-isopropyl-3-methylbutyl benzoate		Yield 68%; δ 7.95 (dd, 2H, <i>J</i> = 10.0, 2.0 Hz), 7.67 (dd, 2H, <i>J</i> = 10.0, 2.0 Hz), 7.30-7.55 (m, 6H), 6.63 (t, 1H, <i>J</i> = 6.5 Hz), 4.38 (s, 2H), 3.57 (d, 2H, <i>J</i> = 7.5 Hz), 2.06 (heptat, 2H, <i>J</i> = 8.5 Hz), 1.38-1.47 (m, 4H), 1.04 (d, 12H, <i>J</i> = 8.5 Hz).
(4) 2-(Benzamidomethyl)-2-isobutyl-4-methylpentyl benzoate		Yield 71%; δ 8.02 (d, 2H, <i>J</i> = 9.5 Hz), 7.76 (d, 2H, <i>J</i> = 9.5 Hz), 7.39-7.60 (m, 6H), 6.84 (t, 1H, <i>J</i> = 7.5 Hz), 4.30 (s, 2H), 3.47 (d, 2H, <i>J</i> = 8.0 Hz), 1.84 (heptat, 2H, <i>J</i> = 7.5 Hz), 1.38-1.47 (m, 4H), 0.96 (d, 12H, <i>J</i> = 8.0 Hz).
(5) 3-(4-fluorobenzamido)-2,2-dimethylpropyl 4-fluorobenzoate		Yield 86.5%; δ 8.08-8.15 (m, 2H), 7.82-7.90 (m, 2H), 7.10-7.18 (m, 4H), 6.95-7.03 (m, 1H), 4.22 (s, 2H), 3.35 (d, 2H, <i>J</i> = 8.0 Hz), 1.09 (s, 6H).
(6) 4-(4-Fluorobenzamido)pentan-2-yl 4-fluorobenzoate		Yield 73%, containing two isomers with a ratio about 3 to 2; δ 8.06 (dd, 2Ha, <i>J</i> = 5.5, 9.0 Hz), 7.99 (dd, 2Hb, <i>J</i> = 5.5, 8.5 Hz), 7.83 (dd, 2Ha, <i>J</i> = 5.5, 8.5 Hz), 7.69 (dd, 2Hb, <i>J</i> = 5.5, 8.5 Hz), 7.01-7.15 (m, 4Ha+4Hb), 6.40 (d, 1Ha, <i>J</i> = 9.0 Hz), 6.14 (d, 1Hb, <i>J</i> = 9.0 Hz), 5.20-5.34 (m, 1Hb), 5.18 (dt, 1Ha, <i>J</i> = 6.5, 6.0 Hz), 4.23-4.36 (m, 1Ha + 1Hb), 2.02-2.12 (m, 1Ha + 1Hb), 1.958 (ddd, 1Hb, <i>J</i> = 4.0, 8.0, 15.0 Hz), 1.79 (ddd, 1Ha, <i>J</i> = 5.5, 6.5, 14.0 Hz), 1.44 (d, 3Ha, <i>J</i> = 6.5 Hz), 1.41 (d, 3Hb, <i>J</i> = 6.5 Hz), 1.34 (d, 3Hb, <i>J</i> = 6.5 Hz), 1.28 (d, 3Ha, <i>J</i> = 6.5 Hz).

Table 1
Halogenated Amide Esters (continued)

Compound	Structure	¹ H NMR (CDCl ₃ as solvent (in ppm)
(7) 2-((4-Fluorobenzamido)methyl)-2-isopropyl-3-methylbutyl 4-fluorobenzoate		Yield 80%; δ 8.04 (dd, 2H, <i>J</i> = 8.5, 5.5 Hz), 7.76 (dd, 2H, <i>J</i> = 8.5, 5.5 Hz), 7.12 (dd, 2H, <i>J</i> = 8.5, 8.5 Hz), 7.09 (dd, 2H, <i>J</i> = 8.0, 9.0 Hz), 6.52 (t, 1H, <i>J</i> = 6.0 Hz), 4.44 (s, 2H), 3.61 (d, 2H, <i>J</i> = 6.0 Hz), 1.85 (heptat, 2H, <i>J</i> = 7.0 Hz), 1.10 (d, 6H, <i>J</i> = 7.0 Hz), 1.09 (d, 6H, <i>J</i> = 7.0 Hz).
(8) 2-((4-Fluorobenzamido)methyl)-2-isobutyl-4-methylpentyl 4-fluorobenzoate		Yield 64%; δ 8.04-8.08 (m, 2H), 7.80-7.83 (m, 2H), 7.09-7.15 (m, 4H), 6.79 (t, 1H, <i>J</i> = 6.5 Hz), 4.31 (s, 2H), 3.45 (d, 2H, <i>J</i> = 6.5 Hz), 1.85 (heptat, 2H, <i>J</i> = 6.5 Hz), 1.38-1.46 (m, 4H), 0.99 (d, 12H, <i>J</i> = 6.5 Hz).
(9) 3-(4-Chlorobenzamido)-2,2-dimethylpropyl 4-chlorobenzoate		Yield 80%; δ 8.00 (d, 2H, <i>J</i> = 11.0 Hz), 7.78 (d, 2H, <i>J</i> = 11.0 Hz), 7.45 (d, 2H, <i>J</i> = 11.0 Hz), 7.42 (d, 2H, <i>J</i> = 11.0 Hz), 6.97 (t, 1H, <i>J</i> = 8.0 Hz), 4.21 (s, 2H), 3.33 (d, 2H, <i>J</i> = 8.0 Hz), 1.08 (s, 6H).
(10) 2-((4-Chlorobenzamido)methyl)-2-isopropyl-3-methylbutyl 4-chlorobenzoate		Yield 80%; δ 7.94 (d, 2H, <i>J</i> = 10.5 Hz), 7.68 (d, 2H, <i>J</i> = 10.5 Hz), 7.42 (d, 2H, <i>J</i> = 10.5 Hz), 7.39 (d, 2H, <i>J</i> = 10.5 Hz), 6.51 (t, 1H, <i>J</i> = 6.5 Hz), 4.44 (s, 2H), 3.60 (d, 2H, <i>J</i> = 8.0 Hz), 2.08 (heptat, 2H, <i>J</i> = 8.8 Hz), 1.09 (d, 6H, <i>J</i> = 8.5 Hz), 1.08 (d, 6H, <i>J</i> = 8.5 Hz).
(11) 2-((4-Chlorobenzamido)methyl)-2-isobutyl-4-methylpentyl 4-chlorobenzoate		Yield 65%; δ 7.97 (d, 2H, <i>J</i> = 8.5 Hz), 7.73 (d, 2H, <i>J</i> = 8.5 Hz), 7.43 (d, 2H, <i>J</i> = 8.5 Hz), 7.41 (d, 2H, <i>J</i> = 8.5 Hz), 6.79 (t, 1H, <i>J</i> = 6.5 Hz), 4.31 (s, 2H), 3.44 (d, 2H, <i>J</i> = 6.5 Hz), 1.85 (heptat, 2H, <i>J</i> = 6.0 Hz), 1.38-1.46 (m, 4H), 0.99 (d, 12H, <i>J</i> = 7.0 Hz).

2. Procatalyst Preparation

[00127] A procatalyst precursor (according to the weight shown in Table 2) and 2.52 mmol of internal electron donor (*i.e.*, halogenated amide ester) are charged into a flask equipped with mechanical stirring and with bottom filtration. 60 ml of a mixed solvent of TiCl₄ and chlorobenzene (1/1 by volume) is introduced into the flask. The mixture is heated to 115°C and remains at the same temperature for 60 minutes with stirring at 250 rpm before filtering off the liquid. 60 ml of mixed solvent is added again and the reaction is allowed to continue at the same desired temperature for 30 minutes with stirring followed by filtration. This process is repeated once. 70 ml of *iso*-octane is used to wash the resultant solid at ambient temperature. After the solvent is removed by filtration, the solid is dried by N₂ flow or under vacuum.

Table 2

Procatalyst Precursor	Weight
MagTi-1 (M)	3.0g
SHAC TM 310 (S)	2.0g

[00128] MagTi-1 is a mixed Mag/Ti precursor with a composition of $\text{Mg}_3\text{Ti}(\text{OEt})_8\text{Cl}_2$ (a MagTi precursor prepared according to example 1 in U.S. Patent No. 6,825,146) with an average particle size of 50 micron. SHACTM 310 is a benzoate-containing catalyst (a BenMag procatalyst precursor with an average particle size of 27 micron) with ethyl benzoate as the internal electron donor made according to Example 2 in U.S. Patent No. 6,825,146, the entire content of which is incorporated herein by reference. Titanium content for each of the resultant procatalyst compositions is listed in Table 3. The peaks for internal donors are assigned according to retention time from GC analysis. No additional characterization is performed.

Table 3
Procatalyst Compositions

Internal Electron Donor	Procatalyst Precursor	Procatalyst #	Procatalyst Compositions		
			Ti (%)	Ethyl Benzoate (%)	Internal Electron Donor (%)
DiBP*	MagTi-1	M-DiBP	2.99	0	12.49
1	MagTi-1	M-1	3.32	0.45	trace
	SHAC TM 310	S-1	3.07	1.08	trace
2	MagTi-1	M-2	3.27	0.53	trace
3	MagTi-1	M-3	3.14	0.17	2.98
	SHAC TM 310	S-3	3.53	0.93	1.92
4	MagTi-1	M-4	3.19	0.18	8.80
	SHAC TM 310	S-4	3.29	0.13	4.59
5	MagTi-1	M-5	3.38	0	trace
	SHAC TM 310	S-5	3.00	0.39	trace
6	MagTi-1	M-6	3.01	0	trace
	SHAC TM 310	S-6	3.12	0.59	trace
7	MagTi-1	M-7	2.91	0	5.11
	SHAC TM 310	S-7	3.25	0.62	5.33
8	MagTi-1	M-8	3.52	0	9.58
	SHAC TM 310	S-8	2.72	0.58	7.72

Internal Electron Donor	Procatalyst Precursor	Pro-catalyst #	Procatalyst Compositions		
			Ti (%)	Ethyl Benzoate (%)	Internal Electron Donor (%)
9	MagTi-1	M-9	5.32	0	trace
	SHAC TM 310	S-9	2.81	2.89	Trace
10	MagTi-1	M-10	3.47	0	1.58
	SHAC TM 310	S-10	3.16	0.99	6.96
11	MagTi-1	M-11	3.97	0	1.80
	SHAC TM 310	S-11	2.72	0.37	6.97

*DiBP = diisobutyl phthalate (comparative)

[00129] 3. Polymerization

[00130] Polymerization is performed in liquid propylene in a 1-gallon autoclave. After conditioning, the reactors are charged with 1375 g of propylene and a targeted amount of hydrogen and brought to 62°C. 0.25 mmol of DCPDMS is added to 7.2 ml of a 0.27 M triethylaluminum solution in isooctane, followed by addition of a 5.0 wt% procatalyst slurry in mineral oil (actual solid weight is indicated in data tables below). The mixture is premixed at ambient temperature for 20 minutes before being injected into the reactor to initiate the polymerization. The premixed catalyst components are flushed into the reactor with isooctane using a high pressure catalyst injection pump. After the exotherm, the temperature is controlled to 67°C. Total polymerization time is 1 hour.

[00131] 4. Polymer Testing

[00132] Polymer samples are tested for settled bulk density, melt flow rate (MFR), xylene solubles (XS), polydispersity index (PDI), and final melting point (T_{MF}). Unless specified, XS are measured using Viscotek method.

[00133] Halogenation of the amide ester improves catalyst productivity and/or polymer properties for both of the SHACTM 310 precursor and the MagTi-1 precursor as shown in Table 4 below.

Table 4
Halogenated Amide Ester Catalyst Performance and Polymer Properties

Internal Electron Donor	Procatlyst Precursor	Example #	Pro-catalyst #	Pro-catalyst (mg)	H ₂ (scc)	Activity (kg/g-hr)	BD	MFR	XS (%)	PDI	T _{MF} (°C)
1	MagTi-1	E-2**	M-1	16.7	4500	8.2	0.29	4.0	4.50	8.24	170.26
	SHAC™ 310	E-3**	S-1	16.7	3000	12.8	0.35	1.2	3.50*	9.00	171.64
2	MagTi-1	E-4**	M-2	16.7	4500	32.0	0.33	3.5	3.37*	5.69	171.62
	SHAC™ 310	E-5**	S-2	8.4	3000	44.1	0.41	2.0	3.87*	5.89	171.58
3	MagTi-1	E-6**	M-3	16.7	13500	12.6	0.27	12.0	2.34	7.50	171.32
	SHAC™ 310	E-7**	S-3	16.7	13500	22.7	0.38	7.6	3.50	9.20	171.76
4	MagTi-1	E-8**	M-4	16.7	13500	14.4	0.28	7.0	2.26	6.52	171.75
	SHAC™ 310	E-9**	S-4	16.7	13500	35.7	0.39	5.6	3.84	7.82	171.86
5	MagTi-1	E-10	M-5	16.7	4500	7.7	0.35	8.1	5.02	7.81	170.28
	SHAC™ 310	E-11	S-5	16.7	4500	19.9	0.37	3.7	5.16	9.61	170.30
6	MagTi-1	E-12	M-6	8.4	1500	41.6	0.36	1.0	2.57	5.73	170.32
	SHAC™ 310	E-13	S-6	8.4	3000	47.7	0.40	1.6	2.27	5.41	171.41
7	MagTi-1	E-14	M-7	16.7	1000	8.9	0.33	4.1	6.16	9.25	170.68
	SHAC™ 310	E-15	S-7	16.7	4500	30.5	0.39	1.0	3.67	9.21	171.73
8	MagTi-1	E-16	M-8	8.4	4500	24.7	0.34	1.7	5.64	8.32	170.82
	SHAC™ 310	E-17	S-8	8.4	13500	51.8	0.39	2.2	2.49	7.72	171.44
9	MagTi-1	E-18	M-9	16.7	1500	5.7	0.29	12.7	9.74	6.98	169.03
	SHAC™ 310	E-19	S-9	8.4	4500	33.3	0.37	3.5	4.77	8.84	170.67
10	MagTi-1	E-20	M-10	16.7	1500	7.6	0.34	3.7	6.15	9.27	169.90
	SHAC™ 310	E-21	S-10	8.4	13500	34.3	0.38	5.0	2.87	8.66	171.56
11	MagTi-1	E-22	M-11	16.7	1500	8.6	0.29	2.9	7.45	8.46	170.11
	SHAC™ 310	E-23	S-11	16.7	13500	37.4	0.37	3.1	1.58	7.02	171.93

* XS by NMR method

** Comparative sample

BD = bulk density

EED = DCPDMS for all polymers in Table 4

[00134] MWD is broadened using halogenated amide esters as internal electron donors compared to conventional DiBP procatalyst. Utilization of a BenMag procatalyst precursor, (*i.e.*, SHACTM 310), significantly improves the catalyst activity and XS while maintaining a broad MWD for a corresponding EED.

[00135] Procatalysts made from the halogenated amide ester internal donors and SHACTM 310 precursor show high catalyst activity, lower XS, and higher TMF. Furthermore, the PDI of the resultant polymer is markedly higher than what can be achieved using DCPDMS with the DiBP-based procatalyst.

[00136] 5. *External Electron Donor*

Table 5

Effect of EEDs on Catalyst Performance and Polymer Properties

IED	Example #	Pro-catalyst #	Procatalyst (mg)	SCA	H ₂ (scc)	Activity (kg/g-hr)	BD	MF	XS (%)	PDI	T _{MF} (°C)
DiBP	E-1**	M-DiBP	16.7	DCPDMS	1500	28.6	0.4	2.5	2.98	4.81	171.48
DiBP	E-58**	M-DiBP-B	4.8	MChDMS	1500	20.0	0.39	4.0	3.03	4.13	170.43
DiBP	E-66**	M-DiBP-B	16.7	BTMSMDMS	500	17.2	0.32	4.3	8.57	5.93	168.89
DiBP	E-59**	M-DiBP	16.7	NPTMS	1000	29.5	0.39	3.4	2.55	3.92	170.00
DiBP	E-60**	M-DiBP-B	16.7	TEOS	200	11.9	0.31	2.6	7.79	4.77	168.57
DiBP	E-61**	M-DiBP-B	16.7	MMBCHC	2000	11.1	0.3	4.1	3.60	6.35	170.23
DiBP	E-62**	M-DiBP-B	16.7	BMMDMH	1500	22.9	0.36	5.7	2.41	3.92	170.13
DiBP	E-63**	M-DiBP-B	16.7	PDODMB	2000	9.9	0.27	5.6	6.99	6.99	169.73
DiBP	E-64**	M-DiBP-B	16.7	TEP	200	11.5	0.31	3.1	7.21	4.53	167.87
DiBP	E-65**	M-DiBP-B	16.7	TMPY	1500	26.9	0.37	3.8	5.71	4.90	170.21
1	E-67**	M-1	33.4	DCPDMS	6000	6.5	0.31	7.0	4.4	8.54	170.65
1	E-68**	M-1	33.4	MChDMS	4500	4.7	0.33	5.6	5.86	8.70	170.18
1	E-73**	M-1	33.4	BTMSMDMS	3000	5.8	0.28	4.2	8.95	12.10	169.70
1	E-69**	M-1	33.4	TEOS	3000	4.1	0.3	5.8	6.98	10.63	169.88
1	E-70**	M-1	33.4	MMBCHC	6000	2.8	0.28	2.3	3.44	9.63	
1	E-71**	M-1	33.4	PDODMB	6000	3.6	0.27	3.8	4.21	9.18	170.79
1	E-72**	M-1	33.4	TEP	3000	4.6	0.29	4.6	6.80	11.56	169.58
1	E-3**	S-1	16.7	DCPDMS	3000	12.8	0.35	1.2	3.50*	9.00	171.64
1	E-74**	S-1	16.7	NPTMS	6000	11.6	0.34	10.7	4.75*	8.72	170.12
8	E-17	S-8	8.4	DCPDMS	13500	48.0	0.39	2.2	2.49	7.72	171.44
8	E-75	S-8	8.4	DIPDMS	15000	34.9	0.39	5.9	2.75	7.76	170.44
8	E-76	S-8	16.7	MChDMS	9000	23.7	0.39	1.6	2.64	7.37	171.76
8	E-85	S-8	16.7	BTMSMDMS	9000	24.6	0.37	1.7	5.01	10.18	170.88
8	E-77	S-8	16.7	NPTMS	9000	29.8	0.39	1.2	1.87	8.74	171.23
8	E-78	S-8	8.4	PTES	9000	38.6	0.39	2.2	3.03	8.57	170.41
8	E-79	S-8	16.7	TEOS	20000	12.2	0.36	6.4	2.61	9.26	171.45

Table 5
Effect of EEDs on Catalyst Performance and Polymer Properties (continued)

IED	Example #	Pro-catalyst #	Procatalyst (mg)	SCA	H ₂ (scc)	Activity (kg/g-hr)	BD	MF	XS (%)	PDI	T _{MF} (°C)
8	E-80	S-8	16.7	MMBCHC	9000	12.4	0.39	0.7	1.61	7.95	172.27
8	E-81	S-8	16.7	BMMDMH	9000	14.5	0.39	3.4	2.74	8.50	171.57
8	E-82	S-8	16.7	PDODMB	9000	16.7	0.4	0.9	2.06	8.33	171.63
8	E-83	S-8	16.7	TEP	9000	20.5	0.38	2.3	2.87	9.56	170.64
8	E-84	S-8	16.7	TMPY	9000	20.7	0.36	5.0	5.89	10.48	170.56

* XS by NMR method ** Comparative example

DCPDMS = dicyclopentylmethoxysilane

MChDMS = methylcyclohexylmethoxysilane

BTMSMDMS = bis(trimethylsilylmethyl)dimethoxysilane

NPTMS = n-propyltrimethoxysilane

TMPY = 2,2,6,6-tetramethylpiperidine

TEOS = tetraethoxysilane

MMBCHC = methyl 1-methoxybicyclo[2.2.1]-hept-5-ene-2-carboxylate

BMMDMH = 3,3-bis(methoxymethyl)-2,5-dimethylhexane

PDODMP = 2,4-pentanediol di(2-methylbenzoate)

TEP = triethyl phosphite

[00137] Many EEDs that are not useful with a DiBP-based procatalyst due to low tacticity (high XS) are suitable for use with a halogenated amide ester-based procatalyst. Surprisingly, the effect of EEDs on the PDI for the halogenated amide ester procatalysts are different than the effect of the same EED when used with a DiBP-based procatalyst. For example, the PDI value for polypropylene produced from DiBP procatalyst using TEOS, BMMDMH, and TEP as EED is lower than the PDI value for polypropylene produced with DiBP procatalyst using DCPDMS as EED. In contrast, the PDI value for polypropylene produced from the halogenated amide ester procatalyst using these same EEDs is greater than the PDI value for polypropylene produced with the DiBP procatalyst using DCPDMS as EED. The effect on XS is also different. The non-alkoxysilane EEDs lead to high XS with the DiBP-based procatalyst, while the same non-alkoxysilane EEDs exhibit low XS with the halogenated amide ester procatalyst (Table 5). Low XS is a basic requirement for many polymer end-use applications. In addition, applicants have surprisingly discovered that EEDs, in particular, the non-silane EEDs, expand the application potential for the halogenated amide ester catalysts and resultant polymers. As shown in Table 5 above, EEDs may be used to manipulate polymer properties and broaden the property variation range of halogenated amide ester-based procatalysts.

Table 6

Effect of EED/ALA on Catalyst Performance and Polymer Properties for Halogenated Amide Ester Catalyst

IED	Ex #	Pro-catalyst #	Procatalyst (mg)	SCA	H ₂ (scc)	Activity (kg/g-hr)	BD	MF	XS (%)	PD I	T _{MF} (°C)
8	E-86	S-8	8.4	C/IPM 5/95	9000	46.8	0.3 8	1.6	3.32	7.9 7	171.1 5
8	E-87	S-8	8.4	D/IPM 40/60	9000	46.1	0.3 9	1.1	3.19	7.5 9	171.9 5
8	E-88	S-8	8.4	N/IPM 10/90	9000	26.9	0.3 8	1.0	3.05	8.4 5	171.9 4
8	E-89	S-8	8.4	D/TMPnDOD Bz 10/90	2000 0	42.9	0.3 9	3.1	1.85	8.2 8	171.2 2
8	E-90	S-8	8.4	D/PTES/IPM 12/28/60	9000	47.5	0.3 8	2.7	3.51	8.4 2	171.7 1

C= MChDMS

N= NPTMS

PTES= propyltriethoxysilane

D= DCPDMS

IPM= isopropyl myristate

TMPnDODBz = 2,2,4-trimethyl-1, 3-pentanediol Dibenzoate

[00138] Introduction of ALAs into the polymerization reaction enhances process operability by rendering the self-limiting property to the catalyst system. Carboxylate esters,

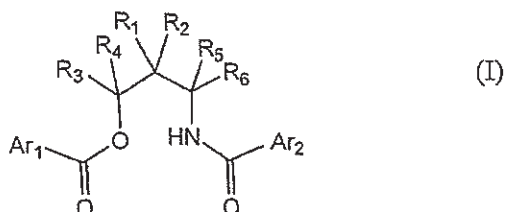
such as isopropyl myristate (IPM) and 2,2,4-trimethyl-1, 3-pentanediol dibenzoate (TMPnDODBz) are suitable self-limiting agents. When an EED/ALA mixture is used with the halogenated amide ester-based procatalyst, the catalyst shows high catalyst activity and the resultant polymer shows low XS, high PDI, and high T_{MF} (Table 6). EEDs may also be used alone or in combination with an ALA.

[00139] High catalyst activity, low XS, high PDI, and high T_{MF} are obtained using the halogenated amide ester procatalyst with a variety of EEDs alone or in combination with an ALA.

[00140] It is specifically intended that the present disclosure not be limited to the embodiments and illustrations contained herein, but include modified forms of those embodiments including portions of the embodiments and combinations of elements of different embodiments as come within the scope of the following claims.

CLAIMS

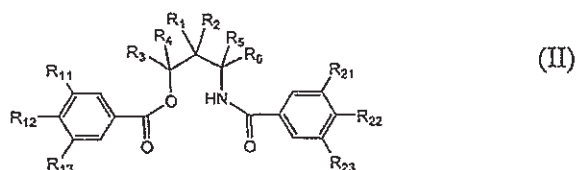
1. A halogenated amide ester having the structure (I):



wherein R_1 - R_6 are the same or different, each of R_1 - R_6 is selected from a group consisting of hydrogen, a halogen, and an acyclic alkyl group having 1-20 carbon atoms, and at least one of R_1 - R_6 is an acyclic alkyl group; and

Ar_1 and Ar_2 are the same or different and each of Ar_1 and Ar_2 is selected from a group consisting of an aryl group having 6-20 carbon atoms and an arylalkyl group having 7-20 carbon atoms, and at least one of Ar_1 and Ar_2 is halogenated.

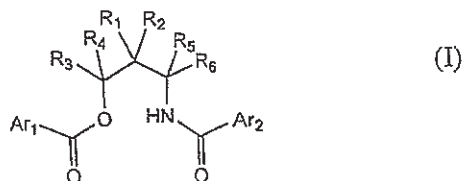
2. The halogenated amide ester of claim 1, wherein each of Ar_1 and Ar_2 is selected from the group consisting of a phenyl group, a naphthyl group, an anthracenyl group, and a phenanthrenyl group.
3. The halogenated amide ester of claim 1, wherein at least two of R_1 - R_6 are an acyclic alkyl group having 1-6 carbon atoms.
4. The halogenated amide ester of claim 1 having the structure (II)



wherein R_{11} - R_{13} and R_{21} - R_{23} are hydrogen, and at least one of R_{11} - R_{13} and at least one of R_{21} - R_{23} is a halogen.

5. The halogenated amide ester of claim 4, wherein each of R_{12} and R_{22} is selected from the group consisting of chlorine and fluorine.
6. The halogenated amide ester of claim 1, wherein each of R_1 and R_2 is a hydrocarbyl group having 1 to 6 carbon atoms.

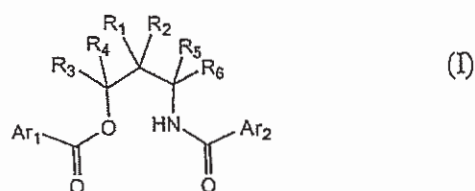
7. The halogenated amide ester of claim 1, wherein each of R₃ and R₅ is a hydrocarbyl group having 1 to 6 carbon atoms.
8. A procatalyst composition comprising:
a combination of a magnesium moiety, a titanium moiety and an internal electron donor comprising a halogenated amide ester of structure (I)



wherein R₁-R₆ are the same or different, each of R₁-R₆ is selected from a group consisting of hydrogen, a halogen, a hydrocarbyl group having 1-20 carbon atoms, and a substituted hydrocarbyl group having 1-20 carbon atoms; and

Ar₁ and Ar₂ are the same or different and each of Ar₁ and Ar₂ is selected from a group consisting of an aryl group having 6-20 carbon atoms and an arylalkyl group having 7-20 carbon atoms, and at least one of Ar₁ and Ar₂ is halogenated.

9. The procatalyst composition of claim 8 comprising a benzoate.
10. A catalyst composition comprising;
a procatalyst composition of claim 8; and
a cocatalyst.
11. The catalyst composition of claim 10 comprising an external electron donor selected from the group consisting of a silicon compound, a bidentate compound, a diether, a diol ester, a carboxylate, an amine, a phosphite, and combinations thereof.
12. The catalyst composition of claim 10 comprising an activity limiting agent selected from the group consisting of a carboxylic acid ester, a diether, a diol ester, and combinations thereof.
13. A process for producing an olefin-based polymer comprising;
contacting, under polymerization conditions, an olefin with a catalyst composition comprising a halogenated amide ester of structure (I):



wherein R_1 - R_6 are the same or different, each of R_1 - R_6 is selected from a group consisting of hydrogen, a halogen, a hydrocarbyl group having 1-20 carbon atoms, and a substituted hydrocarbyl group having 1-20 carbon atoms; and

Ar_1 and Ar_2 are the same or different and each of Ar_1 and Ar_2 is selected from a group consisting of an aryl group having 6-20 carbon atoms and an arylalkyl group having 7-20 carbon atoms, and at least one of Ar_1 and Ar_2 is halogenate; and

forming an olefin-based polymer comprising the halogenated amide ester.

14. The process of claim 13 wherein the olefin is propylene and the process comprises forming a propylene-based polymer having a polydispersity index from about 5.0 to about 20.0.