

CLAIMS

1. A bimodal polyethylene composition comprising a lower molecular weight (LMW) polyethylene component and a higher molecular weight (HMW) polyethylene component, wherein each of the LMW and HMW polyethylene components comprises ethylene-derived monomeric units and (C₃-C₂₀)alpha-olefin-derived comonomeric units; and wherein the bimodal low density polyethylene composition is characterized by each of limitations (a) to (f): (a) a resolved bimodality (resolved molecular weight distribution) showing in a chromatogram of gel permeation chromatography (GPC) of the bimodal low density polyethylene composition, wherein the chromatogram shows a peak representing the HMW polyethylene component, a peak representing the LMW polyethylene component, and a local minimum in a range of Log(molecular weight) ("Log(MW)") 3.0 to 7.0 between the peak representing the HMW polyethylene component and the peak representing the LMW polyethylene component, measured according to the Bimodality Test Method, described later; (b) a density from 0.9300 to 0.9500 gram per cubic centimeter (g/cm³) measured according to ASTM D792-13 Method B; (c) a melt index measured according to ASTM D1238-13 at 190 degrees Celsius (° C.) under a load of 2.16 kilograms (kg) ("I₂" or "MI2") from 0.010 to less than 0.20 gram per 10 minutes (g/10 min.); (d) a flow index measured according to ASTM D1238-13 at 190° C. under a load of 21.6 kg ("I₂₁" or "FI21") from 8.0 to 15 g/10 min.; (e) a flow rate ratio (FRR) of the melt index to the flow index ("I₂₁/I₂") from 100.0 to 800.0; and (f) from greater than 0 to 14 wt% of ethylenic-containing chains having a formula molecular weight (MW) of from greater than 0 to 10,000 grams per mole (g/mol), based on total weight of ethylenic-containing components in the bimodal PE composition.

2. The bimodal polyethylene composition of claim 1 characterized by at least one of limitations (a) to (f): (a) the local minimum of Log(MW) in the GPC chromatogram in a range of from 4.0 to 6.0 Log(MW) between the peak representing the HMW polyethylene component and the peak representing the LMW polyethylene component, measured according to the Bimodality Test Method; (b) density from 0.9310 to 0.9450 g/cm³ measured according to ASTM D792-13 Method B; (c) melt index (I₂) from 0.010 to 0.10 g/10 min. measured according to ASTM D1238-13 (190° C., 2.16 kg); (d) flow index (I₂₁) from 9 to 14 g/10 min.; (e) a flow rate ratio (I₂₁/I₂) from 110 to 600; and (f) from 7.0 to less than 10.0 wt% of ethylenic-containing chains having MW of from greater than 0 to 10,000 g/mol, based on total weight of the ethylenic-containing components in the bimodal PE composition.

3. The bimodal polyethylene composition of claim 2 characterized by at least one of limitations (a) to (f): (a) the local minimum of Log(MW) in the GPC chromatogram in a range of 5.0 to 5.5 Log(MW) between the peak representing the HMW polyethylene component and the peak representing the LMW polyethylene component, measured according to the Bimodality Test Method; (b) density from 0.935 to 0.940 g/cm³ measured according to ASTM D792-13 Method B; (c) melt index (I_2) from 0.045 to 0.095 g/10 min. measured according to ASTM D1238-13 (190° C., 2.16 kg); (d) flow index (I_{21}) from 9 to 14, alternatively from 11 to 13 g/10 min.; (e) a flow rate ratio (I_{21}/I_2) from 150 to 200; and (f) from 8.0 to 9.5 wt% of ethylenic-containing chains having MW of from greater than 0 to 10,000 g/mol.

4. The bimodal polyethylene composition of any one of claims 1 to 3 further characterized by any one of limitations (g) to (l): (g) a molecular mass dispersity (M_w/M_n), $\mathcal{D}_M$ (pronounced D-stroke M), from 5 to 30.1 measured according to the Gel Permeation Chromatography (GPC) Test Method; (h) no measurable amount of long chain branching per 1,000 carbon atoms ("LCB Index"), measured according to LCB Test Method; (i) a shear thinning index value (SHI, $\eta^*(10)/\eta^*(200)$) of greater than 20, measured according to the Shear Thinning Index Test Method; (j) a molecular mass dispersity (M_w/M_n), $\mathcal{D}_M$, of the LMW polyethylene component of from 2.5 to 3.5 after deconvoluting the LMW and HMW polyethylene components of the bimodal PE composition according to the Deconvoluting Test Method; and (k) a M_w/M_n of the HMW polyethylene component from 2.5 to 4.5 measured according to the GPC Test Method after deconvoluting the LMW and HMW polyethylene components of the bimodal PE composition according to the Deconvoluting Test Method; (l) each of (g), (i), (j), and (k).

5. The bimodal polyethylene composition of any one of claims 1 to 4 further characterized by at least one of limitations (i) to (iii): (i) a PENT test value of greater than 1000 hours measured at 90° C. and 2.4 megapascals (MPa) according to the PENT Test Method; and a Pipe Hydrostatic test value of greater than 1000 hours measured at 90° C. and 4.0 MPa according to the Pipe Hydrostatic Test Method 2.

6. The bimodal polyethylene composition of any one of claims 1 to 5, wherein the (C₃-C₂₀)alpha-olefin-derived comonomeric units are further described by any one of limitations (i) to (vii): (i) (C₃-C₁₀)alpha-olefin-derived comonomeric units; (ii) (C₄-C₁₀)alpha-olefin-derived comonomeric units; (iii) (C₄-C₈)alpha-olefin-derived comonomeric units; (iv) 1-

butene-derived comonomeric units; (v) 1-hexene-derived comonomeric units; (vi) 1-octene-derived comonomeric units; and (vii) a combination of any two of (iv) to (vi).

7. A bimodal polyethylene composition made by copolymerizing ethylene (monomer) and at least one (C₃-C₂₀)alpha-olefin (comonomer) with a mixture of a bimodal catalyst system and a trim solution in the presence of molecular hydrogen gas (H₂) and an induced condensing agent (ICA) in one, two or more polymerization reactors under (co)polymerizing conditions; wherein prior to being mixed together the trim solution consists essentially of a (tetramethylcyclopentadienyl)(n-propylcyclopentadienyl)zirconium complex and an inert liquid solvent and the bimodal catalyst system consists essentially of an activator species, a bis(2-pentamethylphenylamido)ethyl)amine zirconium complex and a (tetramethylcyclopentadienyl)(n-propylcyclopentadienyl)zirconium complex, all disposed on a solid support; and wherein the (co)polymerizing conditions comprise a reaction temperature from 85° to 105° C.; a molar ratio of the molecular hydrogen gas to the ethylene (H₂/C₂ molar ratio) from 0.0007 to 0.010; and a molar ratio of the comonomer (Comer) to the ethylene (Comer/C₂ molar ratio) from 0.0005 to 0.02.

8. A method of making a bimodal polyethylene composition, the method comprising contacting ethylene (monomer) and at least one (C₃-C₂₀)alpha-olefin (comonomer) with a mixture of a bimodal catalyst system and a trim solution in the presence of molecular hydrogen gas (H₂) and an induced condensing agent (ICA) in one, two or more polymerization reactors under (co)polymerizing conditions, thereby making the bimodal polyethylene composition; wherein prior to being mixed together the trim solution consists essentially of a (tetramethylcyclopentadienyl)(n-propylcyclopentadienyl)zirconium complex and an inert liquid solvent and the bimodal catalyst system consists essentially of an activator species, a non-metallocene ligand-Group 4 metal complex, and a metallocene ligand-Group 4 metal complex, all disposed on a solid support; and wherein the (co)polymerizing conditions comprise a reaction temperature from 85° to 105° C.; a molar ratio of the molecular hydrogen gas to the ethylene (H₂/C₂ molar ratio) from 0.0007 to 0.010; and a molar ratio of the comonomer (Comer) to the ethylene (Comer/C₂ molar ratio) from 0.0005 to 0.02.

9. The bimodal polyethylene composition of claim 7 or the method of claim 8 may be further described by any one of limitations (i) to (vi): (i) wherein the bimodal catalyst system consists essentially of a bis(2-pentamethylphenylamido)ethyl)amine zirconium complex and a (tetramethylcyclopentadienyl)(n-propylcyclopentadienyl)zirconium complex in a molar ratio thereof from 1.0:1.0 to 5.0:1.0 and a methylaluminoxane species, all disposed by spray-

drying onto the solid support; (ii) wherein the bimodal catalyst system further consists essentially of mineral oil and the solid support is a hydrophobic fumed silica; (iii) wherein the mixture is a suspension of the bimodal catalyst system in mineral oil and the trim solution and wherein the mixture is premade and then fed into the polymerization reactor(s); (iv) wherein the trim solution is made by dissolving (tetramethylcyclopentadienyl)(n-propylcyclopentadienyl)zirconium dimethyl in the inert liquid solvent to give the trim solution; (v) wherein the polymerization reactor(s) is one fluidized bed gas phase reactor and the method is a gas phase polymerization; and (vi) each of (i) to (v).

10. A manufactured article comprising a shaped form of the bimodal polyethylene composition of any one of claims 1 to 7 and 9.

11. The manufactured article of claim 10 selected from: pipes, films, sheets, extruded articles, and injection molded articles.

12. A pipe composed of the bimodal polyethylene composition of any one of claims 1 to 7 and defining an interior volumetric space through which a substance may be transported.

13. A method of transporting a substance, the method comprising moving a substance through the interior volumetric space of the pipe of claim 12.