applications. For example, for certain uses Elmendorf tear in the cross direction (CD Tear) or machine direction (MD Tear) may be too likely, melt strength may be too low, secant modulus may be too low, and/or dart impact strength may be too low. The prior blend has dart impact property that is worse (lower) than that of the prior MCN-LLDPE alone. The more prior ZN-LLDPE that is mixed with the prior MCN-LLDPE, the worse the dart impact property of the blend gets.

[0008] A technical solution to this problem was not obvious from the prior art. A problem to be solved by inventiveness then is to discover a new LLDPE that alone has at least one processability characteristic similar to that of an unblended monomodal ZN-LLDPE and at least one stiffness/mechanical property similar to that of an unblended monomodal MCN-LLDPE.

[0009] Our technical solution to this problem includes a bimodal linear low density polyethylene composition ("inventive bimodal LLDPE composition") made with a bimodal catalyst system, products made therefrom, methods of making and using same, and articles containing same. The inventive bimodal LLDPE composition has a combination of improved properties comprising at least one processability characteristic similar to that of an unblended monomodal ZN-LLDPE and a dart impact property similar to that of an unblended monomodal MCN-LLDPE. In some examples the inventive bimodal LLDPE composition is characterized by a density from 0.9000 to 0.9500 gram per cubic centimeter (g/cm^3), alternatively from 0.9000 to < 0.930 g/cm^3, measured according to ASTM D792-13 Method B.

[0009a] In one aspect, the present disclosure refers to a bimodal linear low density 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 (C_3-C_{20})alpha-olefin-derived comonomeric units; and wherein the bimodal linear low density polyethylene composition is characterized by each of limitations (a) to (d): (a) a resolved bimodality showing in a chromatogram of gel permeation chromatography (GPC) of the bimodal linear low density polyethylene composition, wherein the chromatogram shows a peak representing the HMW polyethylene component, a peak representing the LMW polyethylene component, and a resolved bimodal molecular weight distribution characterized by a local minimum in a range of Log(molecular weight) ("Log(MW)") 1.5 to 5.0 between the peak representing the HMW polyethylene component and the peak representing the LMW polyethylene component, measured according to the Bimodality Test Method; (b) a molecular mass dispersity (M_w/M_n), $Đ_M$, from 5 to 30.1, measured according to the Gel Permeation Chromatography (GPC) Test Method; (c) no measurable, alternatively no detectable, amount of long chain branching per 1,000 carbon atoms ("LCB Index"), measured according to LCB Test Method; and (d) a density from 0.9000 to less than (<) 0.930 gram per cubic centimeter (g/cm^3), measured according to ASTM D792-13 Method B.

[0009b] In another aspect, the present disclosure refers to a method of making a bimodal linear low density polyethylene composition, the method comprising contacting ethylene (monomer) and at least one (C_3-C_{20})alpha-olefin (comonomer) with a mixture of a bimodal catalyst system and a trim solution in the presence of molecular hydrogen gas (H_2) and an inert condensing agent (ICA) in one, two or more polymerization reactors under (co)polymerizing conditions, thereby making the bimodal linear low density 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 80 degrees (°) to 110° Celsius (C.); a molar ratio of the molecular hydrogen gas to the ethylene (H2/C2 molar ratio) from 0.001 to 0.050; and a molar ratio of the comonomer to the ethylene (Comonomer/C2 molar ratio) from 0.005 to 0.10.

[0009c] In another aspect, the present disclosure refers to a manufactured article comprising a shaped form of the bimodal linear low density polyethylene composition as disclosed herein.

[0009d] In another aspect, the present disclosure refers to a method of covering a substance or article in need of covering, the method comprising covering or sealing at least a portion of the substance or the manufactured article as disclosed herein.

[0010] The inventive bimodal LLDPE composition may be characterized by at least one improved property relative to that of a prior bimodal LLDPE.

[0011] The inventive bimodal LLDPE composition is useful in different industrial applications.

DRAWINGS

[0012] Figure (FIG.) 1 contains drawings of structural formulas of (pro)catalysts.

[0013] FIGS. 2 and 3 are GPC chromatograms of inventive examples 1 and 2, respectively, of the inventive bimodal LLDPE composition.

DETAILED DESCRIPTION

[0014] The Summary and Abstract are incorporated here by reference.

[0015] Unpredictably, the inventive bimodal LLDPE composition has at least one improved property such as, for example, at least one improved (increased) processability property and/or at least one improved (increased) stiffness property. The improved processability property may be at least one of decreased extruder barrel pressure, increased sealability (e.g., hot seal/hot tack), decreased tan delta value, and increased shear thinning index value. The improved stiffness property may be at least one of increased Elmendorf tear (CD Tear and/or MD Tear), increased melt strength, increased secant modulus, and increased dart impact strength. In some aspects the inventive bimodal LLDPE

CLAIMS

1. A bimodal linear low density 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 (C_3-C_{20})alpha-olefin-derived comonomeric units; and wherein the bimodal linear low density polyethylene composition is characterized by each of limitations (a) to (d): (a) a resolved bimodality showing in a chromatogram of gel permeation chromatography (GPC) of the bimodal linear low density polyethylene composition, wherein the chromatogram shows a peak representing the HMW polyethylene component, a peak representing the LMW polyethylene component, and a resolved bimodal molecular weight distribution characterized by a local minimum in a range of Log(molecular weight) ("Log(MW)") 1.5 to 5.0 between the peak representing the HMW polyethylene component and the peak representing the LMW polyethylene component, measured according to the Bimodality Test Method; (b) a molecular mass dispersity (M_w/M_n), $Đ_M$, from 5 to 30.1, measured according to the Gel Permeation Chromatography (GPC) Test Method; (c) no measurable, alternatively no detectable, amount of long chain branching per 1,000 carbon atoms ("LCB Index"), measured according to LCB Test Method; and (d) a density from 0.9000 to less than (<) 0.930 gram per cubic centimeter (g/cm^3), measured according to ASTM D792-13 Method B.

2. The bimodal linear low density polyethylene composition of claim 1 described by any one of limitations (i) to (vii): (i) a density from 0.9000 to 0.9294 gram per cubic centimeter (g/cm^3), measured according to ASTM D792-13 Method B; (ii) a melt index (190° C., 2.16 kilograms (kg), "MI_2") from 0.1 to 5.0 grams per 10 minutes (g/10 min.), measured according to the Melt Index MI_2 Test Method; (iii) a tan delta (tan δ) from 5 to 35, measured at 190° C. and 0.1000 radians per second (rad/s) according to Tan Delta Test Method; (iv) both (i) and (ii); (v) both (i) and (iii); (vi) both (ii) and (iii); and (vii) each of (i), (ii), and (iii).

3. The bimodal linear low density polyethylene composition of claim 1 described by any one of limitations (i) to (vii): (i) a density from 0.9000 to 0.9294 gram per cubic centimeter (g/cm^3), measured according to ASTM D792-13 Method B; (ii) a melt index (190° C., 2.16 kilograms (kg), "MI_2") from 0.1 to 5.0 grams per 10 minutes (g/10 min.), measured according to the Melt Index MI_2 Test Method; (iii) a molecular mass dispersity (M_w/M_n), $Đ_M$, of at least one of the LMW and HMW polyethylene components of from > 2.0 to < 3.0, measured according to the GPC Test Method after deconvoluting the LMW and HMW polyethylene components of the bimodal linear low density polyethylene composition according to the Deconvoluting Test Method; (iv) both (i) and (ii); (v) both (i) and (iii); (vi) both (ii) and (iii); and (vii) each of (i), (ii), and (iii).

4. The bimodal linear low density polyethylene composition of any one of claims 1 to 3 described by any one of limitations (i) to (xii): (i) a flow index (190° C., 21.6 kg, "FI_{21}") from 4 to 500 g/10min., measured according to the Flow Index FI_{21} Test Method; (ii) a melt flow ratio (190° C., "MI_{21}/MI_2") 20.0 to 50.0, as calculated according to the Melt Flow Ratio Test Method; (iii) a shear thinning index value from 1.5 to 10, measured according to the Shear Thinning Index Test Method; (iv) a number-average molecular weight (M_n) from 5,000 to 25,000 grams per mole (g/mol), measured according to GPC Test Method; (v) both (i) and (ii); (vi) both (i) and (iii); (vii) both (i) and (iv); (viii) both (ii) and (iii); (ix) both (ii) and (iv); (x) both (iii) and (iv); (xi) any three of (i) to (iv); and (xii) each of (i) to (iv).

5. The bimodal linear low density polyethylene composition of any one of claims 1 to 4 described by any one of limitations (i) to (iv): (i) the (C_3-C_{20})alpha-olefin-derived comonomeric units are derived from 1-butene; (ii) the (C_3-C_{20})alpha-olefin-derived comonomeric units are derived from 1-hexene; (iii) the (C_3-C_{20})alpha-olefin-derived comonomeric units are derived from 1-octene; and (iv) the (C_3-C_{20})alpha-olefin-derived comonomeric units are derived from a combination of any two, alternatively each of 1-butene, 1-hexene, and 1-octene.

6. The bimodal linear low density polyethylene composition of claim 1 made by copolymerizing ethylene (monomer) and at least one (C_3-C_{20})alpha-olefin (comonomer) with a mixture of a bimodal catalyst system and a trim solution in the presence of molecular hydrogen gas (H_2) and an inert condensing agent (ICA) in one, two or more polymerization reactors (e.g., one fluidized bed gas phase reactor) 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 83 degrees (°) to 87° Celsius (C.), a molar ratio of the molecular hydrogen gas to the ethylene (H2/C2 molar ratio) from 0.001 to 0.050; and a molar ratio of the comonomer to the ethylene (Comonomer/C2 molar ratio) from 0.005 to 0.10.

7. A method of making a bimodal linear low density polyethylene composition, the method comprising contacting ethylene (monomer) and at least one (C_3-C_{20})alpha-olefin (comonomer) with a mixture of a bimodal catalyst system and a trim solution in the presence of molecular hydrogen gas (H_2) and an inert condensing agent (ICA) in one, two or more polymerization reactors under (co)polymerizing conditions, thereby making the bimodal linear low density 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 80 degrees (°) to 110° Celsius (C.); a molar ratio of the molecular hydrogen gas to the ethylene (H2/C2 molar ratio) from 0.001 to 0.050; and a molar ratio of the comonomer to the ethylene (Comonomer/C2 molar ratio) from 0.005 to 0.10.

8. The bimodal linear low density polyethylene composition of claim 6 or the method of claim 7 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 (tetramethylcyclopentadienyl)(n-propylcyclopentadienyl)zirconium complex, in a molar ratio thereof from 1.0:1.0 to 5.0:1.0, respectively, alternatively 1.5:1.0 to 2.5:1.0, alternatively 2.0:1.0 to 4.0:1.0, alternatively 2.5:1.0 to 3.49:1.0, alternatively from 2.7:1.0 to 3.3:1.0, alternatively from 2.9:1.0 to 3.1:1.0, alternatively 3.0:1.0, 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 the mixture is premade and then fed into the polymerization reactor(s); (iv) wherein the trim solution is prepared 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).

9. A manufactured article comprising a shaped form of the bimodal linear low density polyethylene composition of any one of claims 1 to 6.

10. The manufactured article of claim 9 selected from: films, sheets, and injection molded articles.

11. The manufactured article of claim 9 or 10 selected from agricultural film, food packaging, garment bags, grocery bags, heavy-duty sacks, industrial sheeting, pallet and shrink wraps, bags, buckets, freezer containers, lids, and toys.

12. A method of covering a substance or article in need of covering, the method comprising covering or sealing at least a portion of the substance or the manufactured article of any one of claims 9 to 11.