stiffness or other mechanical properties that are not sufficient for certain 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 LMDPE that alone has at least one processability characteristic similar to that of an unblended monomodal ZN-LMDPE and at least one stiffness/mechanical property similar to that of an unblended monomodal MCN-LMDPE.

[0009] Our technical solution to this problem includes a bimodal linear medium density polyethylene composition ("inventive bimodal LMDPE composition") made with a bimodal catalyst system, products made therefrom, methods of making and using same, and articles containing same. The inventive bimodal LMDPE has a combination of improved properties comprising at least one processability characteristic similar to that of an unblended monomodal ZN-LMDPE and a dart impact property similar to that of an unblended monomodal MCN-LMDPE. In some examples the inventive bimodal LMDPE composition is characterized by a density from 0.9000 to 0.9500 gram per cubic centimeter (g/cm^3), alternatively from 0.930 to 0.950 g/cm^3, measured according to ASTM D792-13 Method B.

[0009a] In one aspect, the present disclosure refers to a bimodal linear medium 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 medium 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 medium 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 Bimodality Test Method; (b) a molecular mass dispersity (M_w/M_n), $Đ_M$, from 7 to 25, measured according to Gel Permeation Chromatography (GPC) Test Method; (c) no measurable amount of long chain branching per 1,000 carbon atoms ("LCB Index"),

measured according to LCB Test Method; and (d) a density from 0.930 to 0.950 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 medium density polyethylene composition, the method comprising contacting ethylene and at least one (C_3-C_{20})alpha-olefin with a mixture of a bimodal catalyst system and a trim solution in the presence of H_2 gas and an inert condensing agent in one, two or more polymerization reactors under (co)polymerizing conditions, thereby making the bimodal linear medium 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 from 0.001 to 0.050; and a molar ratio of the comonomer to the ethylene from 0.005 to 0.10.

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

[0010] The inventive bimodal LMDPE may be characterized by at least one improved (increased) property. The improvement may be relative to that of a prior bimodal LMDPE.

[0011] The inventive bimodal LMDPE may be used in a number of industrial applications.

DRAWINGS

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

[0013] FIG. 2 is a GPC chromatogram of inventive example 1 of the inventive bimodal LMDPE composition.

DETAILED DESCRIPTION

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

[0015] Unpredictably, the inventive bimodal LMDPE 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

CLAIMS

1. A bimodal linear medium 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 medium 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 medium 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 Bimodality Test Method; (b) a molecular mass dispersity (M_w/M_n), $Đ_M$, from 7 to 25, measured according to Gel Permeation Chromatography (GPC) Test Method; (c) no measurable amount of long chain branching per 1,000 carbon atoms ("LCB Index"), measured according to LCB Test Method; and (d) a density from 0.930 to 0.950 gram per cubic centimeter (g/cm^3), measured according to ASTM D792-13 Method B.

2. The bimodal linear medium density polyethylene composition of claim 1 described by any one of limitations (i) to (iii): (i) 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 Melt Index MI_2 Test Method; (ii) 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; (iii) both (i) and (ii).

3. The bimodal linear medium density polyethylene composition of claim 1 described by any one of limitations (i) to (iii): (i) 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 Melt Index MI_2 Test Method; (ii) 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 medium density polyethylene composition according to Deconvoluting Test Method; (iii) both (i) and (ii).

4. The bimodal linear medium density polyethylene composition of any one of claims 1 to 3 described by any one of limitations (i) to (vii): (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

shear thinning index value from 1.5 to 10, measured according to the Shear Thinning Index Test Method; (iii) a number-average molecular weight (M_n) from 5,000 to 25,000 grams per mole (g/mol) measured according to GPC Test Method; (iv) both (i) and (ii); (v) both (i) and (iii); (vi) both (ii) and (iii); and (vii) each of (i) to (iii).

5. The bimodal linear medium 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 of 1-butene, 1-hexene, and 1-octene.

6. The bimodal linear medium 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 (e.g., liquid alkane) and the bimodal catalyst system consists essentially of an activator species (e.g., a methylaluminoxane species), a bis(2-pentamethylphenylamido)ethyl)amine zirconium complex and a (tetramethylcyclopentadienyl)(n-propylcyclopentadienyl)zirconium complex, all disposed on a solid support (e.g., a hydrophobic fumed silica); 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.

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

8. The bimodal linear medium density polyethylene composition of claim 6 or the method of claim 7 of 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, respectively, 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 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).

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

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

11. The manufactured article of claim 9 or 10 selected from a coated metal pipe, 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. The manufactured article of any one of claims 9 to 11 comprising a coated steel pipe.