CLAIMS

1. A single reactor-made bimodal HDPE copolymer comprising from 45.0 weight percent (wt%) to 56.0 wt% of a higher molecular weight poly(ethylene-*co*-1-alkene) copolymer component (HMW copolymer component) and from 55.0 wt% to 44.0 wt%, respectively, of a lower molecular weight poly(ethylene-*co*-1-alkene) copolymer component (LMW copolymer component), wherein the wt% of the HMW copolymer component and the wt% of the LMW copolymer component are calculated as a percentage of their combined weight from absolute GPC measurements, and wherein the copolymer has each of properties (a) to (g):

(a) a density from 0.941 gram per cubic centimeter (g/cm^3) to 0.957 g/cm^3, measured according to ASTM D792-13 (Method B, 2-propanol);

(b) a melt index (I_5) from 0.20 to 0.40 grams per 10 minutes (g/10 min.), measured according to ASTM D1238-13 (190° C., 5.0 kg);

(c) a high load melt index (HLMI or I_{21}) from 9.0 to 11.0 grams per 10 minutes (g/10 min.), measured according to ASTM D1238-13 (190° C., 21.6 kg);

(d) a melt flow ratio (I_{21}/I_5) from 25 to 45;

(e) a polydispersity index ("PDI"), M_Z/M_W, from 8.0 to 12.0, wherein M_Z is z-average molecular weight based on M_Z(BB) values and M_W is weight-average molecular weight, or M_Z/M_W, from 3.5 to 5.2, alternatively from 4.0 to 5.0, wherein M_Z is z-average molecular weight based on M_Z(abs) values and M_W is as defined above, or both, as measured by absolute gel permeation chromatography;

(f) a slow crack growth ("SCG") resistance of at least 5,000 hours, measured at 90° C. according to the Pennsylvania Edge Notch Tensile ("PENT") Test Method;

(g) a first hydrostatic pipe strength of greater than 3,300 hours, measured according to ISO 1167-2 (110° C., 2.83 megapascals (MPa)), or a second hydrostatic pipe strength of greater than 1,400 hours, measured according to ISO 1167-2 (95° C., 4.39 MPa), or both.

2. The single reactor-made bimodal HDPE copolymer of claim 1, wherein the copolymer has at least one of the properties (a) to (g):

(a) the density is from 0.945 g/cm^3 to 0.953 g/cm^3, alternatively from 0.947 g/cm^3 to 0.951 g/cm^3, alternatively from 0.9485 g/cm^3 to 0.9494 g/cm^3;

(b) the melt index (I_5) is from 0.23 to 0.38 g/10 min., alternatively from 0.25 to 0.36 g/10 min., alternatively from 0.27 to 0.34 g/10 min.;

(c) the high load melt index (I_{21}) is from 9.2 to 10.6 g/10 min., alternatively from 9.4 to 10.4 g/10 min., alternatively from 9.6 to 10.2 g/10 min.;

(d) the melt flow ratio (I_{21}/I_5) is from 23 to 42, alternatively from 25 to 40, alternatively from 28 to 37;

(e) the polydispersity index ("PDI"), M_Z/M_W, is from 8.5 to 11.4, alternatively from 8.9 to 10.9, preferably from 9.3 to 10.1, wherein M_Z is based on M_Z(BB) values; or M_Z/M_W, is from 3.5 to 5.2 wherein M_Z is z-average molecular weight based on M_Z(abs) values and M_W is as defined above; or both;

(f) the slow crack growth ("SCG") resistance (PENT) is at least 6,500 hours, alternatively at least 7,100 hours, alternatively at least 7,800 hours;

(g) the first hydrostatic pipe strength is either greater than 3,400 hours, alternatively greater than 3,500 hours, alternatively greater than 3,700 hours; or the second hydrostatic pipe strength is greater than 1,500 hours, alternatively greater than 1,600 hours, alternatively greater than 1,800 hours.

3. The single reactor-made bimodal HDPE copolymer of claim 1, wherein the wt% of the HMW component is from 47.0 to 54.0 wt%, alternatively from 47.6 to 52.4 wt%; and the wt% of the LMW component is from 53.0 to 46.0 wt%, alternatively from 52.4 to 47.6 wt%, respectively, wherein the foregoing wt% are calculated from absolute GPC measurements.

4. The single reactor-made bimodal HDPE copolymer of claim 1 selected from the group consisting of: a single reactor-made bimodal high-density poly(ethylene-co-1-butene) copolymer, a single reactor-made bimodal high-density poly(ethylene-co-1-hexene) copolymer, or a single reactor-made bimodal high-density poly(ethylene-co-1-octene) copolymer; or wherein the single reactor-made bimodal HDPE copolymer is a single reactor-made bimodal high-density poly(ethylene-co-1-hexene) copolymer.

5. The single reactor-made bimodal HDPE copolymer of claim 1, wherein the copolymer has a molecular weight selected from the group consisting of:

a weight-average molecular weight (M_W) from 200,001 grams per mole (g/mol) to 399,999 g/mol, measured by absolute gel permeation chromatography;

a number-average molecular weight (M_n) from 8,001 g/mol to 29,999 g/mol, measured by absolute gel permeation chromatography;

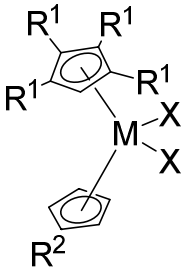
a z-average molecular weight (M_Z) from 1,500,001 g/mol to 3,999,999 g/mol, based on M_Z(BB) values measured by absolute gel permeation chromatography; and

a combination of any two or three of the molecular weights.

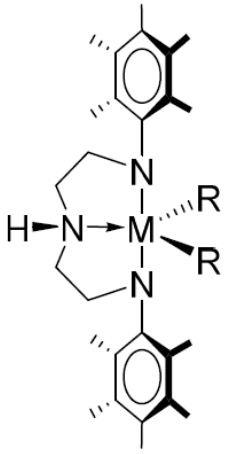
6. A method of making the single reactor-made bimodal HDPE copolymer of claim 1, the method comprising contacting ethylene and 1-alkene with a bimodal catalyst system and a trim catalyst solution in a single gas phase polymerization (GPP) reactor to give the single reactor-

made bimodal HDPE copolymer; wherein the bimodal catalyst system bimodal catalyst system comprises a metallocene catalyst, a post-metallocene catalyst, a solid support, and an activator.

7. The method of claim 6 wherein the metallocene catalyst comprises (n-propylcyclopentadienyl)(tetramethylcyclopentadienyl)zirconium X_2 of formula (I):



(I), wherein each R^1 is methyl ($-CH_3$), R^2 is propyl ($-CH_2CH_2CH_3$), and each X is a leaving group; and wherein the post-metallocene catalyst comprises bis(2-(pentamethylphenylamido)ethyl)amine zirconium dibenzyl, which is a compound of formula (II)



(II), wherein M is Zr and each R is benzyl; and wherein the trim catalyst solution is an additional amount of the metallocene catalyst of formula (I) dissolved in an alkane.

8. A single reactor-made bimodal HDPE copolymer made by the method of claim 6.

9. A formulation comprising the single reactor-made bimodal HDPE copolymer of claim 1 and an additive.

10. A pipe comprising the single reactor-made bimodal HDPE copolymer of claim 1.

11. The pipe of claim 10 that meets standard specifications of ISO 22391 (2009) or standard specifications of GB/T 28799:2020, as described herein.