

CLAIMS

1. A method of increasing bubble stability of a needful bimodal high-density polyethylene (HDPE) resin that comprises a higher molecular weight (HMW) polyethylene polymer constituent and a lower molecular weight (LMW) polyethylene polymer constituent and has an overall density from 0.935 to 0.970 gram per cubic centimeter (g/cm^3) and an overall weight-average molecular weight (M_w) from 200,000 to 450,000 grams per mole (g/mol), which needful bimodal HDPE resin is in need of increased bubble stability because the properties of the needful bimodal HDPE resin are different than those of a prior resin made in the same reactor due to change in reactor conditions and the needful bimodal HDPE resin has a first melt storage modulus G' (at loss modulus $G'' = 3000$ pascals) of less than 1501 pascals and a first complex viscosity ratio SH1000 of from 33.0 to 49.0, the method comprising:

contacting under oxygen-tailoring conditions a melt of the needful bimodal HDPE resin with an oxygen-tailoring mixture consisting essentially of a tailoring effective amount of molecular oxygen gas (O_2) and one or more inert gases, and wherein during the contacting the melt is at a temperature from 235° to 251° C., so as to make an oxygen-tailored bimodal HDPE resin having a second melt storage modulus G' (at $G'' = 3000$ pascals) of from 1565 to 1900 pascals and a second complex viscosity ratio SH1000 of from 38.0 to 50.0;

wherein density is measured according to ASTM D792-13, Method B;

wherein M_w is measured according to the Gel Permeation Chromatography (GPC) Test Method;

wherein each melt storage modulus G' (at $G'' = 3000$ pascals) is measured according to the Melt Storage Modulus Test Method; and

wherein each complex viscosity ratio SH1000 is equal to $\text{Eta}^*0.10/\text{Eta}^*100$, wherein $\text{Eta}^*0.10$ is complex viscosity in pascal-seconds (Pa-s) measured at 0.10 radian per second (rad/s) and wherein Eta^*100 is complex viscosity in Pa-s measured at 100 rad/s, both measured according to Dynamic Mechanical Analysis Test Method.

2. The method of claim 1 wherein the tailoring effective amount of the O_2 gas in the contacting step is as described by any one of limitations (i) to (ii): (i) an O_2 gas concentration of X volume percent (vol%) of the oxygen-tailoring mixture; and (ii) an amount of the O_2 gas is Y weight parts per 1 million weight parts of the needful bimodal HDPE resin (ppmw).

3. The method of claim 1 or 2 wherein the oxygen-tailoring mixture has an O_2 gas concentration of X volume percent (vol%), and wherein the oxygen-tailoring conditions comprise any one of limitations (i) to (iv): (i) the melt is at a temperature from 235° to 245° C.; (ii) the melt is at a temperature from 236° and 241° C.; (iii) the one or more inert gases of the

oxygen-tailoring mixture is molecular nitrogen (N_2), argon, helium, CO_2 , one or more alkane(s), or a combination of any two or more thereof; and (iv) both (iii) and any one of (i) and (ii).

4. The method of any one of claims 1 to 3 wherein the oxygen-tailored bimodal HDPE resin has any one of limitations (i) to (iii): (i) the second melt storage modulus G'' (at $G''=3000$) is from 1565 to 1800 pascals; (ii) the second complex viscosity ratio SH1000 is from 40 to 49.4; (iii) both (i) and (ii).

5. The method of any one of claims 1 to 4 wherein the oxygen-tailored bimodal HDPE resin passes a MLS350 bubble stability test determined according to the Bubble Stability Test Method.

6. The method of any one of claims 1 to 5 wherein the needful bimodal HDPE resin has any one of limitations (i) to (vi): (i) the overall density is from 0.940 to 0.960 g/cm³; (ii) the overall M_w is from 250,000 to 400,000 g/mol; (iii) the first melt storage modulus G' (at $G'' = 3000$ pascals) is from 1001 to 1300 pascals; (iv) the first complex viscosity ratio SH1000 is from 35.0 to 48.0; (v) an overall high-load melt index (HLMI or $I_{21.6}$) of from 8.0 to 10.0 grams per 10 minutes (g/10 min.); and (vi) an overall melt flow ratio-5 (MFR5 or $I_{21.6}/I_{5.0}$) from 25 to 45; wherein the $I_{21.6}$ is measured according to ASTM D1238-13, using conditions of 190° C./21.6 kilograms (kg); and wherein the $I_{5.0}$ is measured according to ASTM D1238-13, using conditions of 190° C./5.0 kg.

7. The method of any one of claims 1 to 6 further comprising preliminary steps (A) and (B) before the contacting step:

(A) determining a molecular weight spread of the needful bimodal HDPE resin, wherein the molecular weight spread is (a1) a ratio of weight-average molecular weight of the HMW polyethylene polymer constituent to weight-average molecular weight of the LMW polyethylene polymer constituent (M_{w-HMW}/M_{w-LMW});

(B) determining the tailoring effective amount of molecular oxygen gas (O_2) that is effective in the contacting step as a function of the determined molecular weight spread of the needful bimodal HDPE resin.

8. The method of claim 7 wherein the needful bimodal HDPE resin has any one of limitations (i) to (iii): (i) the molecular weight spread is (a1) the ratio M_{w-HMW}/M_{w-LMW} , wherein M_{w-HMW}/M_{w-LMW} is from 23 to 45; (ii) the molecular weight spread is (a2) a ratio of number-average molecular weight of the HMW polyethylene polymer constituent to number-average molecular weight of the LMW polyethylene polymer constituent (M_{n-HMW}/M_{n-LMW}), wherein M_{n-HMW}/M_{n-LMW} is from 18 to 30; (iii) the molecular weight spread is (a3) a ratio of z-average molecular weight of the HMW polyethylene polymer constituent to z-average

molecular weight of the LMW polyethylene polymer constituent ($M_{Z\text{-HMW}}/M_{Z\text{-LMW}}$), wherein $M_{Z\text{-HMW}}/M_{Z\text{-LMW}}$ is from 18 to 45; wherein M_w , M_n , and M_z are measured according to the Gel Permeation Chromatography (GPC) Test Method.

9. An oxygen-tailored bimodal HDPE resin made by the method of any one of claims 1 to 8.
10. A blown film comprising the oxygen-tailored bimodal HDPE resin of claim 9.
11. A method of determining whether a bimodal high-density polyethylene (HDPE) resin that comprises a higher molecular weight (HMW) polyethylene polymer constituent and a lower molecular weight (LMW) polyethylene polymer constituent and has an overall density from 0.935 to 0.970 gram per cubic centimeter (g/cm^3) and an overall weight-average molecular weight (M_w) from 200,000 to 450,000 grams per mole (g/mol), is in need of increased bubble stability, the method comprising measuring melt storage modulus G' (at loss modulus $G'' = 3000$ pascals) and complex viscosity ratio (shear thinning) SH1000 of the needful bimodal HDPE resin, and determining the bimodal HDPE resin is a need of increased bubble stability if the melt storage modulus G' (at loss modulus $G'' = 3000$ pascals) is less than 1501 pascals and the complex viscosity ratio (shear thinning) SH1000 is from 33.0 to 49.0.