

CLAIMS

1. A method for producing a multimodal ethylene-based polymer comprising:
passing ethylene monomer, at least one C₃–C₁₂ comonomer, solvent, and optionally hydrogen in both a first solution polymerization reactor, and a second solution polymerization reactor,
wherein the first solution polymerization reactor or the second solution polymerization reactor receives both a first catalyst and a second catalyst,
and wherein a third catalyst is passed to the other of the first or second solution polymerization reactors in which the first and second catalysts are not present;
producing the multimodal ethylene-based polymer having a first ethylene-based component, a second ethylene-based component, and a third ethylene-based component, wherein
the first ethylene-based component is a polymerized reaction product of ethylene monomer and C₃–C₁₂ comonomer catalyzed by the first catalyst, the first ethylene-based component having a first density (ρ_1);
the second ethylene-based component is a polymerized reaction product of ethylene monomer and C₃–C₁₂ comonomer catalyzed by the second catalyst, the second ethylene-based component having a second density (ρ_2); and
the third ethylene-based component is a polymerized reaction product of ethylene monomer and C₃–C₁₂ comonomer catalyzed by the third catalyst, the third ethylene-based component having a third density (ρ_3);
wherein ρ_2 and ρ_1 have different values.
2. The method of claim 1, wherein $\rho_2 > \rho_1$.
3. The method of any preceding claim, wherein $\rho_3 > \rho_2 > \rho_1$.
4. The method of any preceding claim, wherein ρ_2 is greater than ρ_1 by at least 0.005 g/cc and ρ_3 is greater than ρ_2 by at least 0.010 g/cc

5. The method of claim 2, wherein ρ_2 is greater than ρ_1 by 0.010 g/cc to 0.050 g/cc, or preferably from 0.015 g/cc to 0.040 g/cc.
6. The method of claim 2, wherein ρ_3 is greater than ρ_2 by 0.020 g/cc to 0.070 g/cc, or preferably from 0.030 g/cc to 0.060 g/cc.
7. The method of any preceding claim, wherein the first catalyst or second catalyst comprises a post-metallocene catalyst, and the third catalyst is a Ziegler-Natta catalyst.
8. The method of any preceding claim, wherein the first solution polymerization reactor, and the second solution polymerization reactor operate in series or in parallel, and wherein at least one of the first solution polymerization reactor or the second solution polymerization reactor comprises a continuous stirred tank reactor, a loop reactor, or combinations thereof.
9. The method of any preceding claim, wherein the multimodal ethylene-based polymer has a molecular weight distribution ($M_{w(GPC)}/M_{n(GPC)}$) of at least 5, or preferably from 5 to 12.
10. The method of any preceding claim,
wherein the first ethylene-based component has a C₃–C₁₂ α -olefin comonomer incorporation of at least 0.5 mol.%, and the second ethylene-based component has a C₃–C₁₂ α -olefin comonomer incorporation of at least 0.5 mol.% and
wherein the multimodal ethylene-based polymer comprises from 20 to 40% by weight of the first ethylene-based component, from 10 to 40% by weight of the second ethylene-based component, 25 to 60% by weight of the third ethylene-based component.
11. The method of any preceding claim, wherein the multimodal ethylene-based polymer has a melt index (I_2) from 0.1 to 10.0 g/10 min, a density from 0.900 to 0.940 g/cc, and an I_{10}/I_2 value of from 9 to 15, where I_{10} is measured according to ASTM D1238 at a load of 10 kg and temperature of 190 °C.

12. The method of any preceding claim, wherein the density of the first ethylene-based component is from 0.860 to 0.915 g/cc, and a weight-average molecular weight ($M_{w(GPC)}$) of 128,000 g/mol to 363,000 g/mol.
13. The method of any preceding claim, wherein the density of the second ethylene-based component is from 0.880 to 0.940 g/cc, and a weight-average molecular weight ($M_{w(GPC)}$) of 88,500 g/mol to 363,000 g/mol.
14. The method of any preceding claim, wherein the density of the third ethylene-based component is from 0.935 to 0.965 g/cc, and a weight-average molecular weight ($M_{w(GPC)}$) is less than 88,500 g/mol.
15. The method of any preceding claim, wherein the multimodal ethylene-based polymer has a Crystallization Elution Fractionation (CEF) weight fraction greater than 23% and a weight-average molecular weight ($M_{w(CEF)}$) greater than 100,000 g/mol at a temperature range from 20°C to $T_{critical}(T_c)$.