CLAIMS

1. A polyisoolefin-based copolymer composition comprising a multimodal molecular weight distribution, wherein:

the multimodal molecular weight distribution comprises:

a first molecular weight fraction having a peak molecular weight (M_p) of less than about 300 kg/mol, and

a second molecular weight fraction having a peak molecular weight (M_p) at least 3 times greater than the M_p of the first molecular weight fraction, and

the copolymer composition has a level of unsaturation of greater than about 3 mol %.

2. The composition according to claim 1, wherein the copolymer composition has a bulk weight average molecular weight greater than about 250 kg/mol.

3. The composition according to claim 1, wherein:

the first molecular weight fraction has a peak molecular weight (M_p) of less than about 300 kg/mol,

the second molecular weight fraction has a peak molecular weight (M_p) of greater than about 1000 kg/mol, and

the copolymer composition has a bulk weight average molecular weight greater than about 250 kg/mol and a level of unsaturation of greater than about 3.5 mol %.

4. The composition according to claim 1, wherein the multimodal molecular weight distribution comprises a bimodal molecular weight distribution.

5. The composition according to claim 1, wherein the copolymer composition has a phase angle of 60° or less when the copolymer composition has a complex modulus of 10,000 Pa or less.

6. The composition according to claim 1, wherein the copolymer has a gel content of less than 3.0 wt %.

7. The composition according to claim 1, wherein the copolymer composition has a zero shear viscosity compared to Mooney viscosity that is at least 1.5 times greater than zero shear viscosity compared to Mooney viscosity for a unimodal polyisoolefin-based copolymer

composition having otherwise a same composition.

8. The composition according to claim 1, wherein the copolymer comprises isoolefin monomers having from 4 to 16 carbon atoms and at least 4 mol % of β-pinene or multi-olefin monomers having from 4-14 carbon atoms.

9. The composition according to claim 1, wherein the second molecular weight fraction comprises 3-15 wt % of the copolymer, based on total weight of the copolymer.

10. The composition according to claim 1, wherein the copolymer composition is free of a cross-linking agent and free of a branching agent and wherein the copolymer comprises inter-chain branching without a cross-linking agent and without a branching agent.

11. A process for producing a polyisoolefin-based copolymer composition, the process comprising: co-polymerizing 70-96 vol % isoolefin monomer and 4-30 vol % β-pinene or multi-olefin monomer, based on volume of isoolefin monomer and β-pinene or multi-olefin monomer, in a solution comprising 0-30 vol % aliphatic hydrocarbon diluent, based on volume of the solution, and an alkylaluminum halide initiator system to produce a polyisoolefin-based copolymer composition having a multimodal molecular weight distribution comprising a first molecular weight fraction having a peak molecular weight (M_p) of less than about 300 kg/mol and a second molecular weight fraction having a peak molecular weight (M_p) at least 3 times greater than the M_p of the first molecular weight fraction, the copolymer composition having a level of unsaturation of greater than about 3.5 mol %.

12. A process for producing a polyisoolefin-based copolymer composition, the process comprising: co-polymerizing 70-96 vol % isoolefin monomer and 4-30 vol % β-pinene or multi-olefin monomer, based on volume of isoolefin monomer and β-pinene or multi-olefin monomer, in a solution comprising 0-30 vol % aliphatic hydrocarbon diluent, based on volume of the solution, and an alkylaluminum halide initiator system to produce a polyisoolefin-based copolymer composition having a multimodal molecular weight distribution comprising a first molecular weight fraction having a peak molecular weight (M_p) of less than about 300 kg/mol and a second molecular weight fraction having a peak molecular weight (M_p) of greater than about 1000 kg/mol, the copolymer composition having a weight average molecular weight (M_w) greater than about 250 kg/mol and a level of

unsaturation of greater than about 3.5 mol %.

13. The process according to claim 11, wherein the diluent comprises hexane and is present in an amount of from 0.1-10 vol %.

14. The process according to claim 11, wherein the co-polymerization is performed at a temperature of -80° C. or greater.

15. The process according to claim 11, wherein, following polymerization, the copolymer is present in the diluent at a solids fraction of greater than 15%.

16. The process according to claim 12, wherein:

the diluent comprises hexane and is present in an amount of from 0.1-10 vol %;

the co-polymerization is performed at a temperature of -80° C. or greater; and

following polymerization, the copolymer is present in the diluent at a solids fraction of greater than 15%.

17. The composition according to claim 2, wherein:

the multimodal molecular weight distribution is a bimodal molecular weight distribution;

the bulk weight average molecular weight is greater than about 350 kg/mol;

the level of unsaturation is greater than about 4.5 mol %;

the copolymer composition has a phase angle of 60° or less when the copolymer composition has a complex modulus of 10,000 Pa or less;

the copolymer composition has a gel content of less than 3.0 wt %;

the copolymer composition has a zero shear viscosity compared to Mooney viscosity that is at least 1.5 times greater than zero shear viscosity compared to Mooney viscosity for a unimodal polyisoolefin-based copolymer composition having otherwise a same composition;

the copolymer comprises:

isoolefin monomers having from 4 to 7 carbon atoms selected from the group consisting of isobutene, 2-methyl-1-butene, 3-methyl-1-butene, 2-methyl-2-butene, 4-methyl-1-pentene and mixtures thereof; and

at least 4 mol % of β-pinene or multi-olefin monomers having from 4-14 carbon atoms selected from the group consisting of isoprene, butadiene, 2-

methylbutadiene, 2,4-dimethylbutadiene, piperyline, 3-methyl-1,3-pentadiene, 2,4-hexadiene, 2-neopentylbutadiene, 2-methyl-1,5-hexadiene, 2,5-dimethyl-2,4-hexadiene, 2-methyl-1,4-pentadiene, 2-methyl-1,6-heptadiene, cyclopentadiene, methylcyclopentadiene, cyclohexadiene, 1-vinyl-cyclohexadiene and mixtures thereof;

the copolymer comprises about 0-75 wt % of the second molecular weight fraction, based on total weight of the copolymer; and

the copolymer composition is free of a cross-linking agent and free of a branching agent and wherein the copolymer comprises inter-chain branching without a cross-linking agent and without a branching agent.