WHAT IS CLAIMED:

1. A thermoplastic copolymer comprising plural acrylated polyol monomeric units having different degrees of acrylation of hydroxyl groups, wherein the acrylated polyol monomeric units have an average degree of acrylation greater than 1 and less than the number of the hydroxyl groups of the polyol.

2. The thermoplastic copolymer of claim 1, wherein the thermoplastic copolymer has:

a) a linear or branched-chain structure; or

b) a molecular weight of at least 1 KDa, optionally wherein the thermoplastic copolymer has a molecular weight ranging from 50 KDa to 10 MDa; or

c) a transition temperature (T_g) below 0 ºC, optionally wherein the thermoplastic copolymer has a T_g ranging from -60 ºC to -15 ºC.

3. The thermoplastic copolymer of claim 1, wherein the polyol is selected from the group consisting of ethylene glycol, propylene glycol, dipropylene glycol, 1,2,4-butanetriol, 1,7-heptanediol, glycerol, panaxatriol, panaxytriol, talose, balsaminol B, momordol, erythritol, enterodiol, xylitol, miglitol, sorbitol, mannitol, galactitol, isomalt, maltitol, aldohexose, aldopentose, aldotetrose, aldotriose, aldose, allose, altrose, arabinose, amylopectin, amylose, dextrose, erythrose, fructose, galactose, glucose, gulose, hexose, idose, ketohexose, ketose, lactose, lyxose, maltose, mannose, pentose, ribose, saccharose, sucrose, talose, tetrose, triose, xylose, amylopectin, and stereoisomers thereof; and optionally

wherein the polyol is glycerol, optionally wherein the average degree of acrylation ranges from 1.001 to 2.9, or from 1.001 to 1.25; or

wherein the polyol is sorbitol, optionally wherein the average degree of acrylation ranges from 1.001 to 3; or

wherein the polyol is dextrose, optionally wherein the average degree of acrylation ranges from 1.001 to 3.

4. The thermoplastic copolymer of claim 1, wherein one or more acrylated polyol monomeric units contain one or more alkoxy groups derived from esterification of the un-acrylated hydroxy groups, optionally

wherein one or more acrylated polyol monomeric units contain one or more methoxy or ethoxy groups.

5. A thermoplastic block copolymer comprising at least one PA block and at least one PB block, wherein PA represents a polymer block comprising one or more units of monomer A and PB represents a polymer block comprising one or more units of monomer B, with monomer A being an acrylated polyol monomeric unit having different degrees of acrylation of hydroxyl groups, wherein the acrylated polyol monomeric unit has an average degree of acrylation greater than 1 and less than the number of the hydroxyl groups of the polyol, and monomer B being a radically polymerizable monomer.

6. The thermoplastic block copolymer of claim 5, wherein the PA block and PB block each have a linear or branched-chain structure; and optionally

wherein one or more acrylated polyol monomeric units of the PA block contain one or more alkoxy groups derived from esterification of the un-acrylated hydroxy groups; or

further comprising at least one PC block, wherein PC represents a polymer block comprising one or more units of monomer C, with monomer C being a radically polymerizable monomer; or

wherein the block copolymer has a molecular weight ranging from 5 to 10 MDa; or

wherein the PA block has a glass transition temperature (Tg) below 0 °C.

7. The thermoplastic block copolymer of claim 5, wherein the polyol of the monomer A is selected from the group consisting of ethylene glycol, propylene glycol, dipropylene glycol, 1,2,4-butanetriol, 1,7-heptanediol, glycerol, panaxatriol, panaxytriol, talose, balsaminol B, momordol, erythritol, enterodiol, xylitol, miglitol, sorbitol, mannitol, galactitol, isomalt, maltitol, aldohexose, aldopentose, aldotetrose, aldotriose, aldose, allose, altrose, arabinose, amylopectin, amylose, dextrose, erythrose, fructose, galactose, glucose, gulose, hexose, idose, ketohexose, ketose, lactose, lyxose, maltose, mannose, pentose, ribose, saccharose, sucrose, talose, tetrose, triose, xylose, amylopectin, and stereoisomers thereof; and optionally

wherein the polyol of the monomer A is glycerol, or sorbitol, or dextrose.

8. The thermoplastic block copolymer of claim 5, wherein the monomer B is a vinyl, acrylic, diolefin, nitrile, dinitrile, acrylonitrile monomer, a monomer with reactive functionality, or a crosslinking monomer; optionally

selected from the group consisting of styrene, α-methyl styrene, t-butyl styrene, vinyl xylene, vinyl naphthalene, vinyl pyridine, divinyl benzene, methyl acrylate, methyl (meth)acrylate, ethyl (meth)acrylate, propyl (meth)acrylate, butyl (meth)acrylate, heptyl (meth)acrylate, hexyl (meth)acrylate, acrylonitrile, adiponitrile, methacrylonitrile, butadiene, isoprene, radically polymerizable plant oils, and mixtures thereof; optionally

wherein the monomer B is radically polymerizable plant oil selected from the group consisting of soybean oil, linseed oil, corn oil, flax seed oil, and rapeseed oil.

9. A thermoplastic statistical copolymer having a general formula of: $[A_i\text{-}B_j\text{-}C_k]_q$,

wherein:

A represents monomer A, which is an acrylated polyol monomeric unit having different degrees of acrylation of hydroxyl groups, wherein the acrylated polyol monomeric unit has an average degree of acrylation greater than 1 and less than the number of the hydroxyl groups of the polyol;

B represents monomer B, which is a radically polymerizable monomer;

C represents monomer C, which is a radically polymerizable monomer;

provided that the monomer B is different than the monomer A, and the monomer C is different than the monomer A or monomer B;

i, *j*, and *k* are average number of repeating units of monomer A, monomer B, and monomer C, respectively, such that *i* and *j* are each greater than 0 and less than 1, *k* is 0 to less than 1, provided that $i + j + k = 1$; and

q represents the number average degree of polymerization and ranges from 10 to 100,000**.**

10. The thermoplastic statistical copolymer of claim 9, wherein the acrylated polyol monomeric unit contains one or more conjugated sites; optionally

wherein one or more acrylated polyol monomeric units of the monomer A contain one or more alkoxy groups derived from esterification of the un-acrylated hydroxy groups.

11. The thermoplastic statistical copolymer of claim 9, wherein the polyol of the monomer A is selected from the group consisting of ethylene glycol, propylene glycol, dipropylene glycol, 1,2,4-butanetriol, 1,7-heptanediol, glycerol, panaxatriol, panaxytriol, talose, balsaminol B, momordol, erythritol, enterodiol, xylitol, miglitol, sorbitol, mannitol, galactitol, isomalt, maltitol, aldohexose, aldopentose, aldotetrose, aldotriose, aldose, allose, altrose, arabinose, amylopectin, amylose, dextrose, erythrose, fructose, galactose, glucose, gulose, hexose, idose, ketohexose, ketose, lactose, lyxose, maltose, mannose, pentose, ribose, saccharose, sucrose, talose, tetrose, triose, xylose, amylopectin, and stereoisomers thereof; and optionally

wherein the polyol of the monomer A is glycerol, or sorbitol, or dextrose.

12. The thermoplastic statistical copolymer of claim 9, wherein the monomer B and the monomer C, if present, are each independently vinyl, acrylic, diolefin, nitrile, dinitrile, acrylonitrile monomers, a monomer with reactive functionality, or a crosslinking monomer; optionally

each independently styrene, α-methyl styrene, t-butyl styrene, vinyl xylene, vinyl naphthalene, vinyl pyridine, divinyl benzene, methyl acrylate, methyl (meth)acrylate, ethyl (meth)acrylate, propyl (meth)acrylate, butyl (meth)acrylate, heptyl (meth)acrylate, hexyl (meth)acrylate, acrylonitrile, adiponitrile, methacrylonitrile, butadiene, isoprene, radically polymerizable plant oils, or mixtures thereof; optionally

wherein the radically polymerizable plant oil is selected from the group consisting of soybean oil, linseed oil, corn oil, flax seed oil, and rapeseed oil.

13. An asphalt binder composition comprising:

the thermoplastic copolymer of claim 1, the thermoplastic block copolymer of claim 5, or the thermoplastic statistical copolymer of claim 9; and

a crumb rubber.

14. An adhesive or sealant composition comprising:

the thermoplastic copolymer of claim 1, the thermoplastic block copolymer of claim 5, or the thermoplastic statistical copolymer of claim 9; and

a tackifier, and/or a plasticizer, and/or a solvent.

15. A tire composition comprising:

the thermoplastic copolymer of claim 1, the thermoplastic block copolymer of claim 5, or the thermoplastic statistical copolymer of claim 9; and

a rubber compound.

16. A fracking fluid composition comprising:

water;

sand;

the thermoplastic copolymer of claim 1, the thermoplastic block copolymer of claim 5, or the thermoplastic statistical copolymer of claim 9 as a chemical additive; and

optionally a thermoplastic polymer block added to confer a desired fluid property to the thermoplastic copolymer, thermoplastic statistical copolymer, or thermoplastic block copolymer.

17. A method of making a thermoplastic copolymer or block copolymer, comprising:

providing an acrylated polyol composition comprising plural acrylated polyol monomeric units having different degrees of acrylation of hydroxyl groups,
wherein the acrylated polyol composition has an average degree of acrylation greater than 1 and less than the number of the hydroxyl groups of the polyol; and

polymerizing the acrylated polyol composition through controlled radical polymerization, to form the thermoplastic copolymer or block copolymer.

18. The method of claim 17, further comprising:

a) wherein said providing an acrylated polyol composition comprises:

reacting a polyol with an acrylic reagent in a stoichiometric ratio of the acrylic reagent to the polyol ranging from 1 to 3; optionally

wherein said reacting is carried out at a temperature of 30 to 130 °C, or

wherein said acrylic reagent is an unsaturated carboxylic acid or acidic halide selected from the group consisting of acrylic acid, acryloyl chloride, methacrylic acid, and other acid or acidic halide terminated with a vinyl; or

b) wherein said polymerizing is carried out to produce the thermoplastic copolymer or block copolymer having a linear or branched-chain structure; or

c) wherein said polymerizing is carried out under conditions effective to produce the thermoplastic copolymer or block copolymer with a molecular weight of at least 1 KDa without gelation, optionally

wherein said polymerizing is carried out under conditions effective to produce the thermoplastic copolymer with a molecular weight of 50 KDa to 10 MDa without gelation; or

d) wherein said polymerizing is carried out by atom transfer radical polymerization (ATRP), in the presence of a solvent, a catalyst, a counter catalyst, an initiator, and a ligand; or

e) wherein said polymerizing is carried out by reversible addition-fragmentation chain-transfer polymerization (RAFT), in the presence of a free radical initiator, a solvent, and a chain transfer agent; optionally

wherein said polymerizing is carried out at a temperature of 50 to 120 °C, or

wherein said solvent is selected from the group consisting of toluene, THF, chloroform, cyclohexane, dioxane, dimethyl sulfoxide, dimethyl formamide, acetone, acetonitrile, n-butanol, n-pentnaol, chlorobenzene, dichloromethane, diethylether, tert-butanol, 1,2,-dichloroethylene, diisopropylether, ethanol, ethylacetate, ethylmethylketone, heptane, hexane, isopropylalcohol, isoamylalcohol, methanol, pentane, n-propylacohol, pentachloroethane, 1,1,2,2,-tetrachloroethane, 1,1,1,-trichloroethane, tetrachloroethylene, tetrachloromethane, trichloroethylene, water, xylene, benzene, nitromethane, glycerol, and a mixture thereof, optionally methanol, glycerol, or a mixture thereof, or

wherein said polymerizing is carried out in a solvent with the monomer having a concentration, when dissolved in the solvent, ranging from 1 % to 90 %, or

wherein the free radical initiator is selected from the group consisting of benzoyl peroxide and azobisisobutyronitrile, or

wherein the chain transfer agent is a thiocarbonylthio compound, a dithioester compound, a trithiocarbonate compound, a dithiocarbamate compound, or a xantate compound capable of reversible association with polymerizable free radicals, optionally 1-phenylethyl benzodithioate, 1-phenylethyl 2-phenylpropanedithioate, or dibenzyl carbonotrithioate; or

f) wherein the polyol is selected from the group consisting of ethylene glycol, propylene glycol, dipropylene glycol, 1,2,4-butanetriol, 1,7-heptanediol, glycerol, panaxatriol, panaxytriol, talose, balsaminol B, momordol, erythritol, enterodiol, xylitol, miglitol, sorbitol,

mannitol, galactitol, isomalt, maltitol, aldohexose, aldopentose, aldotetrose, aldotriose, aldose, allose, altrose, arabinose, amylopectin, amylose, dextrose, erythrose, fructose, galactose, glucose, gulose, hexose, idose, ketohexose, ketose, lactose, lyxose, maltose, mannose, pentose, ribose, saccharose, sucrose, talose, tetrose, triose, xylose, amylopectin, and stereoisomers thereof; optionally

wherein the polyol is glycerol, optionally wherein the average degree of acrylation ranges from 1.001 to 2.9, optionally from 1.001 to 1.25, or

wherein the polyol is sorbitol, optionally wherein the average degree of acrylation ranges from 1.001 to 3, or

wherein the polyol is dextrose, optionally wherein the average degree of acrylation ranges from 1.001 to 3; or

g) further comprising reacting the thermoplastic copolymer or block copolymer with an organic acid to esterify the un-acrylated hydroxy groups in one or more acrylated polyol monomeric units, optionally

wherein the organic acid is formic acid, acetic acid, hexanoic acid, ethanoic acid, or propanoic acid; or

h) wherein said polymerizing is carried out in the presence of a solvent, a catalyst, a counter catalyst, a macromolecular initiator, and a ligand to form the thermoplastic block copolymer; and optionally further comprising

providing a radically polymerizable monomer different than the acrylated polyol monomeric unit; and

polymerizing the radically polymerizable monomer through atom transfer radical polymerization (ATRP) with the formed thermoplastic block copolymer as a macromolecular free radical initiator to add an additional block to the thermoplastic block copolymer; or

i) wherein said polymerizing is carried out in the presence of a free radical initiator, a solvent, and a macromolecular chain transfer agent to form the thermoplastic block copolymer; and optionally further comprising

providing a radically polymerizable monomer different than the acrylated polyol monomeric unit; and

polymerizing the radically polymerizable monomer through reversible addition-fragmentation chain-transfer polymerization (RAFT) with the formed thermoplastic block

copolymer as a macromolecular chain transfer agent to add an additional block to the thermoplastic block copolymer; or

j) further comprising

chemically modifying the thermoplastic copolymer or block copolymer with a crosslinking agent, allowing the thermoplastic copolymer or block copolymer to undergo a crosslinking reaction at an elevated temperature; or

k) further comprising

chemically modifying the thermoplastic copolymer or block copolymer with a reagent to confer an acidic or basic functionality to the thermoplastic copolymer or block copolymer, making the thermoplastic copolymer or block copolymer a pH adjusting agent; or

l) further comprising

chemically modifying the thermoplastic copolymer or block copolymer with a reagent to confer a biocidic functionality to the thermoplastic copolymer or block copolymer, making the thermoplastic copolymer or block copolymer a biocide agent.

19. A method of preparing a thermoplastic statistical copolymer, said method comprising:

providing monomer A, which is an acrylated polyol monomeric unit having different degrees of acrylation of hydroxyl groups, wherein the acrylated polyol monomeric unit has an average degree of acrylation greater than 1 and less than the number of the hydroxyl groups of the polyol;

providing a radically polymerizable monomer, represented by B; and

polymerizing monomer A and monomer B simultaneously, via reversible addition-fragmentation chain-transfer polymerization (RAFT), in the presence of a free radical initiator and a chain transfer agent to form the thermoplastic statistical copolymer.

20. The method of claim 19 further comprising:

a) prior to said polymerizing:

providing a radically polymerizable monomer, represented by C, wherein monomer C is different than monomer A or monomer B, wherein said polymerizing comprises polymerizing monomer A, monomer B, and monomer C simultaneously, via RAFT, in the

presence of the free radical initiator and the chain transfer agent to form the thermoplastic statistical copolymer, and optionally wherein the monomer C is radically polymerizable plant oil selected from the group consisting of soybean oil, linseed oil, corn oil, flax seed oil, and rapeseed oil; or

b) wherein the polyol of the monomer A is glycerol, or sorbitol, or dextrose; or

c) wherein the monomer B is a vinyl, acrylic, diolefin, nitrile, dinitrile, acrylonitrile monomer, a monomer with reactive functionality, or a crosslinking monomer, optionally

selected from the group consisting of styrene, α-methyl styrene, t-butyl styrene, vinyl xylene, vinyl naphthalene, vinyl pyridine, divinyl benzene, methyl acrylate, methyl (meth)acrylate, ethyl (meth)acrylate, propyl (meth)acrylate, butyl (meth)acrylate, heptyl (meth)acrylate, hexyl (meth)acrylate, acrylonitrile, adiponitrile, methacrylonitrile, butadiene, isoprene, and mixtures thereof; or

d) reacting the thermoplastic statistical copolymer with an organic acid to esterify the un-acrylated hydroxy groups in one or more acrylated polyol monomeric units, optionally

wherein the organic acid is formic acid, acetic acid, hexanoic acid, ethanoic acid, or propanoic acid.

21. An asphalt composition comprising:

i) an asphalt component;

ii) a crumb rubber having a weight percentage in the range of 1 % to 15 %, optionally wherein the crumb rubber is a ground tire rubber, optionally comprising particles capable of passing a 30 mesh screen; and

iii) the thermoplastic copolymer of claim 1, the thermoplastic block copolymer of claim 5, or the thermoplastic statistical copolymer of claim 9 as an asphalt additive, modifier, and/or filler having a weight percentage in the range of 0.01 % to 1.05 %.

22. The asphalt composition of claim 21, wherein the weight concentration of the thermoplastic copolymer, block copolymer or statistical copolymer relative to the weight of the crumb rubber has a range of 2.5 % to 6.5 %; and optionally

wherein the polyol is glycerol and the average degree of acrylation ranges from 1.001 to 1.25, the thermoplastic copolymer, block copolymer or statistical copolymer has a molecular weight ranging from 50 KDa to 200 KDa, and the weight concentration of the thermoplastic copolymer relative to the weight of the crumb rubber is 4.5 %, optionally

wherein said asphalt composition has one or more of the following properties: a high temperature grade higher than 78 °C, a low temperature grade no higher than -29 °C, a grade range higher than 107 °C, a minimum mixing temperature lower than 171 °C, and a minimum compaction temperature lower than 161 °C; or

wherein the polyol is glycerol and the average degree of acrylation ranges from 1.001 to 1.25, the thermoplastic copolymer, block copolymer or statistical copolymer has a molecular weight ranging from 50 KDa to 200 KDa, and the weight concentration of the thermoplastic copolymer relative to the weight of the crumb rubber is 6.5 %, optionally

wherein said asphalt composition has one or more of the following properties: a high temperature grade higher than 82 °C, a low temperature grade no higher than -28.5 °C, a grade range higher than 110 °C, a minimum mixing temperature lower than 179 °C, and a minimum compaction temperature lower than 168 °C.

23. The asphalt composition of claim 21, wherein said asphalt composition is stable and homogenous for at least 3 days under a temperature of 130 °C to 180 °C.

24. A method for preparing a homogeneous asphalt composition, comprising:

mixing the thermoplastic copolymer of claim 1, the thermoplastic block copolymer of claim 5, or the thermoplastic statistical copolymer of claim 9 as an asphalt additive, modifier, and/or filler, with a weight percentage in the range of 0.01 % to 1.05 %, into an asphalt composition comprising i) an asphalt component, and ii) a crumb rubber having a weight percentage in the range of 1 % to 15 %, to form a homogeneous asphalt composition; and optionally further comprising:

a) wherein the crumb rubber is a ground tire rubber, optionally comprising particles capable of passing a 30 mesh screen; or

b) wherein the weight concentration of the thermoplastic copolymer, block copolymer or statistical copolymer relative to the weight of the crumb rubber ranges from 2.5 % to 6.5 %; optionally

wherein the polyol is glycerol and the average degree of acrylation ranges from 1.001 to about 1.25, the thermoplastic copolymer, block copolymer or statistical copolymer has a molecular weight ranging from 50 KDa to 200 KDa, and the weight concentration of the thermoplastic copolymer relative to the weight of the crumb rubber is 4.5 %, or

wherein the polyol is glycerol and the average degree of acrylation ranges from 1.001 to about 1.25, the thermoplastic copolymer, block copolymer or statistical copolymer has a molecular weight ranging from 50 KDa to 200 KDa, and the weight concentration of the thermoplastic copolymer relative to the weight of the crumb rubber is 6.5 %; or

c) wherein said mixing is carried out at a temperature of 130 °C to 180 °C; or

d) wherein said mixing occurs at a location remote from the location at which the homogeneous asphalt composition is used, and wherein the asphalt composition is stable and homogenous for at least 3 days at a temperature of 130 °C to 180 °C.

25. A method for preparing a fracking liquid, comprising:

mixing the thermoplastic copolymer of claim 1, the thermoplastic block copolymer of claim 5, or the thermoplastic statistical copolymer of claim 9 as a chemical additive, with water, and sand.

26. A method for preparing an adhesive or sealant composition, comprising:

mixing the thermoplastic copolymer of claim 1, the thermoplastic block copolymer of claim 5, or the thermoplastic statistical copolymer of claim 9, with a tackifier, and/or a plasticizer, and/or a solvent.