Claims

1. Polymer particles comprising:

a plurality of polymeric stabilizing components, each polymeric stabilizing component comprising one or more hydrophilic polymer chains; and

a plurality of hydrophobic polymer chains, each hydrophobic polymer chain covalently bonded to one or more of the polymeric stabilizing components, wherein:

the polymer particles are monodisperse and have a coefficient of variation based on their diameter of less than 20%,

wherein the hydrophobic polymer chains are formed as copolymers, and wherein:

when the hydrophobic polymer chains are copolymers, they are formed from a first set of monomers that are hydrophobic selected from one or more of styrene and derivatives thereof, acrylates, and alkylacrylates;

a second set of monomers selected from one or more of monomers having a carboxylic acid group, a monomer having hydroxyl group, a monomer having an amino group, and a monomer having an epoxy group; and

the weight:weight ratio of the first set of monomers to the second set of monomers is from 40:1 to 1:1, such as from 20:1 to 2:1.

2. The polymer particles according to Claim 1, wherein the particles have a coefficient of variation based on their diameter of less than 15%, such as less than 10%, such as less than 5%, optionally wherein the particles have a coefficient of variation based on their diameter of less than or equal to 2%.

3. The polymer particles according to Claim 2, wherein the particles have a coefficient of variation based on their diameter of less than or equal to 1%.

4. The polymer particles according to any one of the preceding claims, wherein one or more of the following apply:

(a) the polymer particles have an average diameter of from 50 to 1000 nm, such as from 100 to 600 nm, such as from 120 to 450 nm, such as from 150 to 400 nm, such as from 200 to 350 nm;

(b) the hydrophilic polymer chains of the polymeric stabilizing components are selected from the group consisting of poly(vinylpyrrolidone), polyethylenimine, polyacrylic acid, polyvinyl alcohol, water soluble polysaccharides (e.g. hydroxypropyl methylcellulose, chitosan, and blends thereof), copolymers therof and blends therof, optionally wherein the hydrophilic polymer chains of the polymeric stabilizing components are poly(vinylpyrrolidone); and

(c) the hydrophobic polymer chains are formed from monomers selected from one or more of styrene and derivatives thereof, acrylates, and alkylacrylates, optionally wherein the hydrophobic polymer chains are formed from monomers selected from one or more of styrene, butyl acrylate**,** 2,2,2-trifluoro ethyl methacrylate, methyl methacrylate, 4-methylstyrene, 3-methylstyrene, and 4-tertbutylstyrene, for example, the hydrophobic polymer chains are formed from styrene;

(d) the weight:weight ratio of the plurality of polymeric stabilizing components to the plurality hydrophobic polymer chains is from 1:1000 to 1:1, such as from 1:500 to 1:2, such as from 1:300 to 1:3, such as from 1:150 to 1:5;

(e) wherein the particles are functionalised with a sulfate salt with the formula $-SO_4^-\ M^+$, where the dash represents the point of attachment to the polymer particles and M^+ represents Na^+, K^+, or NH_4^+.

5. The polymer particles according to any one of the preceding claims, wherein the hydrophobic polymer chains are crosslinked.

6. The polymer particles according to Claim 5, wherein:

when the hydrophobic polymer chains are crosslinked, the crosslinked polymer chains are formed by a crosslinking agent that reacts with the first and/or, when present, second set of monomers, optionally wherein the crosslinking agent is a monomer having two or more unsaturated groups optionally wherein:

the weight:weight ratio of the first set of monomers to the crosslinking agent is from 40:1 to 1:1, such as from 20:1 to 2:1.

7. The polymer particles according to Claim 6, wherein:

(ai) the first set of monomers is selected from one or more of styrene, butyl acrylate**,** 2,2,2-trifluoro ethyl methacrylate, methyl methacrylate, 4-methylstyrene, 3-methylstyrene, and 4-tertbutylstyrene; and/or

(bi) the second set of monomers is selected from one or more of acrylic acid, methacrylic acid, 2-carboxyethyl acrylate, acrylamide, methacrylamide, allylamine, (hydroxyethyl)methacrylate, hydroxypropyl methacrylate, 4-hydroxybutyl acrylate, glycidyl methacrylate, allyl glycidyl ether, 1,2-epoxy-5-hexene, 1,4-diamino-6-diallylamino-1,3,5-triazine, diallylamine, and triallylamine; and/or

(ci) the crosslinking agent is selected from one or more of divinylbenzene, ethylene glycol dimethylacrylate, bisphenol A dimethacrylate, butanediol dimethacrylate, tricyclodecane dimethanol diacrylate, pentaerythritol triacrylate, tripropylene glycol diacrylate, propoxylated neopentyl diacrylate, pentaerythritol triacrylate, ditrimethylolpropane tetraacrylate,

dipentaerythritol pentaacrylate, dipentaerythritol penta/hexa-acrylate, tripropylene diacrylate, trimethylol propane ethoxylate triacrylate, trimethylol propane propoxylate triacrylate, di(trimethylolpropane) tetraacrylate, glycerol propoxylate triacrylate, pentaerythritol propoxylate triacrylate, poly(ethylene glycol) diacrylate, poly(propylene glycol) diacrylate, and tri(propylene glycol) diacrylate, optionally wherein:

(aii) the first set of monomers is styrene; and/or

(bii) the second set of monomers is selected from one or more of N,N′-methylenebis(acrylamide), 1,4-Diamino-6-diallylamino-1,3,5-triazine, diallylamine, and triallylamine; and/or

(cii) the crosslinking agent is selected from one or more of divinylbenzene, ethylene glycol dimethylacrylate, bisphenol A dimethacrylate.

8. The polymer particles according to Claim 7, wherein:

(aii) the first set of monomers is styrene; and/or

(bii) the second set of monomers is selected from one or more of N,N′-methylenebis(acrylamide), 1,4-Diamino-6-diallylamino-1,3,5-triazine, diallylamine, and triallylamine; and/or

(cii) the crosslinking agent is selected from one or more of divinylbenzene, ethylene glycol dimethylacrylate, bisphenol A dimethacrylate.

9. A method of generating polymer particles, the method comprising:

(A) reacting a hydrophilic polymeric stabilizer compound with a water-soluble initiator compound in water to form a macroinitiator complex in an aqueous solution;

(B) forming a biphasic polymerisation reaction mixture by adding one or more water-immiscible monomers to the macroinitiator complex in an aqueous solution, and allowing the reaction to run for a first period of time until particle nucleation occurs; and

(C) allowing the reaction to continue for a second period of time after the first period of time to provide the polymer particles, wherein the polymer particles are monodisperse and have a coefficient of variation based on their diameter of less than 20%,

wherein when the reaction is continued for a second period of time, a second set of monomers is added to the reaction mixture,

which second set of monomers is selected from one or more of a monomer having a carboxylic acid group, a monomer having hydroxyl group, a monomer having an amino group, and a monomer having an epoxy group, and

wherein the weight:weight ratio of the first set of monomers to the second set of monomers is from 40:1 to 1:1, such as from 20:1 to 2:1.

10. The method according to Claim 9, wherein the particles have a coefficient of variation based on their diameter of less than 15%, such as less than 10%, such as less than 5%, optionally wherein the particles have a coefficient of variation based on their diameter of less than or equal to 2%.

11. The method according to Claim 10, wherein the particles have a coefficient of variation based on their diameter of less than or equal to 1%.

12. The method according to any one or Claims 9 to 11, wherein the polymer particles have an average diameter of from 50 to 1000 nm, such as from 100 to 600 nm, such as from 120 to 450 nm, such as from 150 to 400 nm, such as from 200 to 350 nm.

13. The method according to any one of Claims 9 to 12, wherein the water-soluble initiator comprises one or more of a peroxide initiator, a persulfate salt and an azo initiator, optionally wherein:
(a) the water-soluble initiator is selected from one or more of tertiary-amyl hydroperoxide, potassium persulfate, sodium persulfate, ammonia persulfate, 4,4'-azobis(4-cyanovaleric acid), 2,2'-azobis[2-methyl-N-(2-hydroxyethyl)propionamide, 2,2'-azobis[N-(2-carboxyethyl)-2-methylpropionamidine]hydrate, 2,2′-azobis(2-methylpropionamidine) dihydrochloride, 2,2''-azobis[2-(2-imidazolin-2-yl)propane], and 2,2'-azobis[2-(2-imidazolin-2-yl)propane] dihydrochloride, optionally wherein the water-soluble initiator is selected from one or more of potassium persulfate, sodium persulfate, and ammonia persulfate, further optionally wherein the water-soluble initiator is sodium persulfate; or
(b) the water-soluble initiator is a redox pair, optionally wherein the redox pair is selected from ascorbic acid and hydrogen peroxide or ammonia persulfate and sodium bisulfite.

14. The method according to any one of Claims 9 to 13, wherein the hydrophilic polymeric stabilizer compound is selected from the group consisting of poly(vinylpyrrolidone), polyethylenimine, polyacrylic acid, polyvinyl alcohol, water soluble polysaccharides (e.g. hydroxypropyl methylcellulose, chitosan, and blends thereof), copolymers therof and blends therof, optionally wherein the hydrophilic polymeric stabilizer compound is poly(vinylpyrrolidone), further optionally wherein the hydrophilic polymeric stabilizer compound is a water soluble polysaccharide, such as hydroxypropyl methylcellulose.

15. The method according to any one of Claims 9 to 14 wherein one or more of the following apply:

(a) the one or more water-immiscible monomers are selected from one or more of styrene and derivatives thereof, acrylates, and alkylacrylates, optionally wherein the one or more water-immiscible monomers are selected from one or more of styrene, butyl acrylate**,** 2,2,2-trifluoro ethyl methacrylate, methyl methacrylate, 4-methylstyrene, 3-methylstyrene, and 4-tertbutylstyrene, further optionally wherein the one or more water-immiscible monomers are styrene; and

(b) the weight:weight ratio of the hydrophilic polymeric stabilizer compound to the water-immiscible monomers is from 1:1000 to 1:1, such as from 1:500 to 1:2, such as from 1:300 to 1:3, such as from 1:150 to 1:5.

16. The method according to any one of Claims 9 to 15, wherein when the reaction is continued for a second period of time, a crosslinking agent is added to the reaction mixture,

which crosslinking agent is a monomer having two or more unsaturated groups.

17. The method according to any one of Claims 9 to 16, wherein:

(ia) the second set of monomers is selected from one or more of acrylic acid, methacrylic acid, 2-carboxyethyl acrylate, acrylamide, methacrylamide, allylamine, (hydroxyethyl)methacrylate, hydroxypropyl methacrylate, 4-hydroxybutyl acrylate, glycidyl methacrylate, allyl glycidyl ether, 1,2-epoxy-5-hexene, 1,4-diamino-6-diallylamino-1,3,5-triazine, diallylamine, and triallylamine; and/or

(ib) the crosslinking agent is selected from one or more of divinylbenzene, ethylene glycol dimethylacrylate, bisphenol A dimethacrylate, butanediol dimethacrylate, tricyclodecane dimethanol diacrylate, pentaerythritol triacrylate, tripropylene glycol diacrylate, propoxylated neopentyl diacrylate, pentaerythritol triacrylate, ditrimethylolpropane tetraacrylate, dipentaerythritol pentaacrylate, dipentaerythritol penta/hexa-acrylate, tripropylene diacrylate, trimethylol propane ethoxylate triacrylate, trimethylol propane propoxylate triacrylate, di(trimethylolpropane) tetraacrylate, glycerol propoxylate triacrylate, pentaerythritol propoxylate triacrylate, poly(ethylene glycol) diacrylate, poly(propylene glycol) diacrylate, and tri(propylene glycol) diacrylate, optionally wherein:

(iia) the second set of monomers is selected from one or more of N,N′-methylenebis(acrylamide), 1,4-Diamino-6-diallylamino-1,3,5-triazine, diallylamine, and triallylamine; and/or

(iib) the crosslinking agent is selected from one or more of divinylbenzene, ethylene glycol dimethylacrylate, bisphenol A dimethacrylate.

18. The method according to any one of Claims 9 to 17, wherein:

when present, the weight:weight ratio of the first set of monomers to the crosslinking agent is from 40:1 to 1:1, such as from 20:1 to 2:1.

19. The method according to any one of Claims 9 to 18, wherein:

(a) the molar ratio of the water-soluble initiator compound to the hydrophilic polymeric stabilizer compound is from 10:1 to 10,000:1, such as from 20:1 to 5,000:1, such as from 30:1 to 1000:1, such as from 50:1 to 500:1; and/or

(b) the concentration of the hydrophilic polymeric stabilizer compound in the aqueous solution is from 0.01% to 20 wt%, such as from 0.05% to 10 wt%, such as from 0.1% to 5.0 wt%, or wherein the process is substantively free of surfactants and organic solvents.