CLAIMS

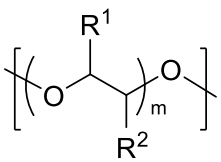
1. A thermogelling polymer comprising one or more repeating units derived from a hydrophilic polymer, one or more repeating units derived from a thermoresponsive polymer, and one or more repeating units derived from a vinyl-containing diol monomer,

wherein the one or more repeating units derived from a hydrophilic polymer, the one or more repeating units derived from a thermoresponsive polymer, and the one or more repeating units derived from a vinyl-containing diol monomer are chemically coupled together by at least one of urethane/carbamate, carbonate, ester linkages or combinations thereof,

optionally wherein the thermogelling polymer has a polydensity index (PDI) falling in a range of from 1 to 2.

2. The thermogelling polymer according to claim 1, wherein

the one or more repeating units derived from a hydrophilic polymer is/are represented by general formula (1); the one or more repeating units derived from a thermoresponsive polymer is/are represented by general formula (2); the one or more repeating units derived from a vinyl-containing diol monomer is/are represented by general formula (3); and the at least one of urethane/carbamate, carbonate, ester linkages or combinations thereof is/are represented by general formula (5):



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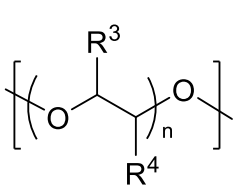

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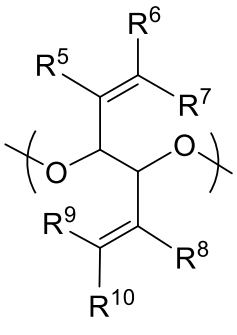

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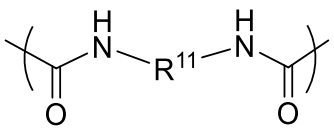


(5)

wherein

R^1 to R^{10} are each independently selected from H, alkyl, or optionally substituted alkyl;

$m \geq 1$;

$n \geq 1$;

R^{11} is alkyl or optionally substituted alkyl.

3. The thermogelling polymer according to claim 2, wherein general formula (1) comprises poly(ethylene glycol) (PEG), general formula (2) comprises poly(propylene glycol) (PPG), general formula (3) comprises 1,5-hexadiene-3,4-diol (HDDO), and general formula (5) comprises hexamethylene diisocyanate (HMDI).

4. The thermogelling polymer according to any one of claims 2 to 3, wherein general formula (1) is present in an amount of between 0 mass % to 90 mass % of the thermogelling polymer, general formula (2) is present in an amount of between 0 mass % to 90 mass % of the thermogelling polymer, general formula (3) is present in an amount of from 0.1 mass % to 40 % of the thermogelling polymer, and general formula (5) is present in an amount of from 10 mass % to 60 mass % of the thermogelling polymer; and/or the thermogelling polymer comprises 0.01 mmol/g to 7 mmol/g of vinyl groups (e.g., $-CH=CH_2$).

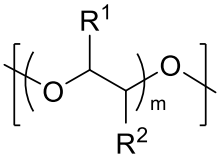
5. A functionalized thermogelling polymer comprising one or more repeating units derived from a hydrophilic polymer, one or more repeating units derived from a thermoresponsive polymer, and one or more repeating units derived from a functionalized vinyl-containing diol monomer,

wherein the one or more repeating units derived from a hydrophilic polymer, the one or more repeating units derived from a thermoresponsive polymer, and the one or more repeating units derived from a functionalized vinyl-containing diol monomer are chemically coupled together by at least one of urethane/carbamate, carbonate, ester linkages or combinations thereof,

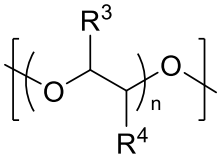
optionally wherein the functionalized thermogelling polymer has one or more of the following properties: a pH value falling in a range of from 1 to 10; a gelation temperature falling in a range of from 4 ºC to 60 ºC; a crossover modulus falling in a range of from 5 Pa to 1000 Pa; a storage modulus (G') in a range of from 4 Pa to 5000 Pa at about 37 ºC; or a complex viscosity falling in a range of from 1 Pa.s to 500 Pa.s at about 37 ºC.

6. The functionalized thermogelling polymer according to claim 5, wherein

the one or more repeating units derived from a hydrophilic polymer is/are represented by general formula (1); the one or more repeating units derived from a thermoresponsive polymer is/are represented by general formula (2); the one or more repeating units derived from a functionalized vinyl-containing diol monomer is/are represented by general formula (4); and the at least one of urethane/carbamate, carbonate, ester linkages or combinations thereof is/are represented by general formula (5):



(1)



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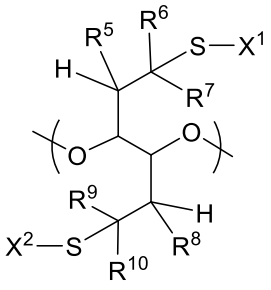

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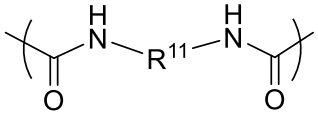


(5)

wherein

R^1 to R^{10}, m and n are as defined above;

X^1-S and X^2-S each independently comprises a thiol-containing functional group;

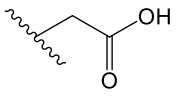
R^{11} is alkyl or optionally substituted alkyl,

optionally wherein the functionalized thermogelling polymer has a functional group density for X^1 and/or X^2 falling in a range of from 0.01 mmol/g to 7 mmol/g.

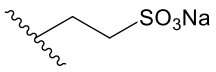
7. The functionalized thermogelling polymer according to claim 6, wherein general formula (1) comprises poly(ethylene glycol) (PEG), general formula (2) comprises poly(propylene glycol) (PPG), general formula (3) comprises 1,5-hexadiene-3,4-diol (HDDO), and general formula (5) comprises hexamethylene diisocyanate (HMDI).

8. The functionalized thermogelling polymer according to claim 6 or 7, wherein X^1 and X^2 are each independently a moiety comprising one or more of a carboxylic acid, an amino acid, a sulfonate, an alkylsulfonate, an aminehydrochloride, an alcohol, a diol, a benzene, an alkylbenzene, or derivatives thereof.

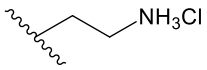
9. The functionalized thermogelling polymer according to any one of claims 6 to 8, where X^1 and X^2 are each independently selected from the group consisting of the following structures or their derivatives thereof:



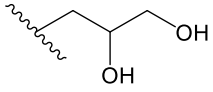
Thioglycolic acid



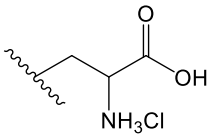
Sodium 2-mercaptoethanesulfonate



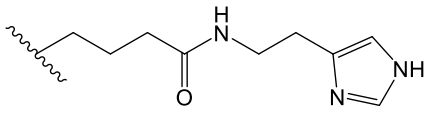
2-Aminoethanethiol hydrochloride



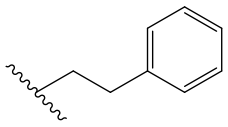
Thioglycerol



Cysteine hydrochloride



His-SH



2-Phenylethanethiol

10. A method of preparing a thermogelling polymer, the method comprising:

coupling one or more hydrophilic polymers, one or more thermoresponsive polymers, and one or more vinyl-containing diol monomers in the presence of a coupling agent to obtain a thermogelling polymer,

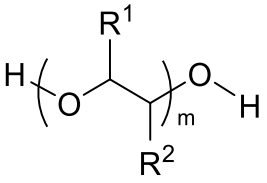
wherein the coupling agent comprises a urethane/carbamate forming agent, carbonate forming agent, ester forming agent, or combinations thereof,

optionally wherein the coupling agent is a diisocyanate selected from the group consisting of hexamethylene diisocyanate (HMDI), tetramethylene diisocyanate, cyclohexane diisocyanate, tetramethylxylene diisocyanate, dodecylene diisocyanate, tolylene 2,4-diisocyanate, and tolylene 2,6-diisocyanate,

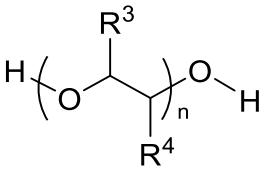
optionally wherein the coupling step is performed at an elevated temperature falling in a range of from 60 °C to 150 °C; and/or the coupling step is carried out for at least 2 hours; and/or the coupling step is carried out in the presence of an anhydrous solvent selected from the group consisting of toluene, benzene, and xylene.

11. The method according to claim 10, wherein

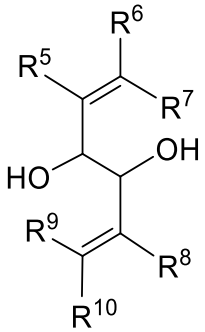
the one or more hydrophilic polymers is/are represented by general formula (6); the one or more thermoresponsive polymers is/are represented by general formula (7); and the one or more vinyl-containing diol monomers is/are represented by general formula (8),



(6)



(7)



(8)

wherein R^1 to R^{10}, m and n are as defined above,

optionally wherein the one or more hydrophilic polymers represented by general formula (6), one or more thermoresponsive polymers represented by general formula (7), and one or more vinyl-containing diol monomers

represented by general formula (8) are mixed in a mass ratio of 1-20 : 1-10 : 0.01-3,

optionally wherein the coupling agent is added in a ratio of 1-2 : 1-2 relative to one or more vinyl-containing diol monomers represented by general formula (8).

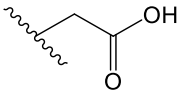
12. The method according to claim 10 or 11, wherein the coupling step is carried out in the presence of a metal-containing or non-metal containing catalyst that is capable of catalysing formation of urethane/carbamate, carbonate, ester linkages, or combinations thereof from alcohols and a suitable isocyanate precursor or derivatives thereof,

optionally wherein the metal-containing catalyst comprises a tin-based catalyst and/or a zinc-based catalyst.

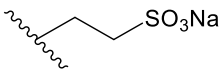
13. The method according to any one of claims 10 to 12, wherein the method further comprises functionalizing the thermogelling polymer with one or more thiols to obtain a functionalized thermogelling polymer with thiol-containing functional groups X^1—S and X^2—S, where X^1 and X^2 each independently comprises a functional group,

optionally wherein X^1 and X^2 are each independently a moiety comprising one or more of a carboxylic acid, an amino acid, a sulfonate, an alkylsulfonate, an aminehydrochloride, an alcohol, a diol, a benzene, an alkylbenzene, or derivatives thereof,

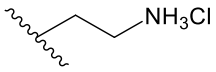
optionally wherein X^1 and X^2 are each independently selected from the group consisting of the following structures or their derivatives thereof:



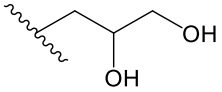
Thioglycolic acid



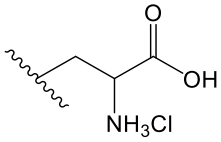
Sodium 2-mercaptoethanesulfonate



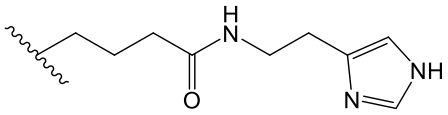
2-Aminoethanethiol hydrochloride



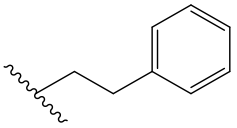
Thioglycerol



Cysteine hydrochloride



His-SH



2-Phenylethanethiol,

optionally wherein functionalizing the thermogelling polymer with one or more thiols has a functionalization efficiency falling in a range of from 5 % to 100 %.

14. The method according to claim 13, wherein functionalizing the thermogelling polymer is carried out in the presence of a radical initiator, photoinitiator, ultraviolet (UV) light and/or anhydrous solvent,

optionally wherein functionalizing the thermogelling polymer is carried out in the presence of UV light for at least 30 minutes; and

optionally wherein the anhydrous solvent is selected from the group of anhydrous tetrahydrofuran (THF) and anhydrous methanol.

15. The method according to any one of claims 13 to 14, wherein the one or more thiols is added in a molar ratio of 20-1 : 1-20, optionally 3:1, relative to the vinyl groups in the thermogelling polymer;

and/or the photoinitiator is added in a molar ratio of at least 3-1 : 1-3, optionally 2:1 relative to the vinyl groups in the functionalized thermogelling polymer, and optionally wherein the photoinitiator comprises 2-hydroxy-4'-(2-hydroxyethoxy)-2-methylpropiophenone.