However, conventional hydrogels may not be sufficiently strong for the applications that they are used in, may not be able to self-heal when damaged, or may be toxic to a living human or animal body.

There is a need to provide a hydrogel that overcomes, or at least ameliorates, one or more of the disadvantages described above. There is a need to provide a copolymer that can, in one application, be used to form the hydrogel.

Summary

There is provided a copolymer comprising an oxygenated polyaromatic alcohol and a poly (alkylene oxide) alkyl ether (meth)acrylate.

There is provided a hydrogel comprising a copolymer having an oxygenated polyaromatic alcohol and a poly (alkylene oxide) alkyl ether (meth)acrylate.

According to an aspect, there is provided a hydrogel comprising: 1 wt% to 4 wt% of a copolymer comprising an oxygenated polyaromatic alcohol and a poly (alkylene oxide) alkyl ether (meth)acrylate; and 6 wt% to 14 wt% of a cyclic oligosaccharide.

The hydrogel may further comprise a cyclic oligosaccharide. Advantageously, the presence of the oxygenated polyaromatic alcohol in the copolymer may aid in the formation of the hydrogel from a mixture of the copolymer and the cyclic oligosaccharide. Conversely, the inventors had found that a mixture of poly (alkylene oxide) alkyl ether (meth)acrylate and the cyclic oligosaccharide was not able to form a hydrogel, even at high concentrations. Hence, the presence of the oxygenated polyaromatic alcohol in the copolymer and consequently the mixture was necessary to enable a hydrogel to be formed.

The hydrogel may be able to "self-heal" (that is, regain the gel state of the hydrogel after the hydrogel was broken) in a short period of time, as compared to conventional hydrogels (not formed based on the above copolymer with a cyclic oligosaccharide) which can take hours to "self-heal".

There is provided a method for forming a hydrogel comprising the step of adding a cyclic oligosaccharide to a copolymer to form a mixture that undergoes gelation to form the hydrogel, wherein the copolymer comprises an oxygenated polyaromatic alcohol and a poly (alkylene oxide) alkyl ether (meth)acrylate.

According to another aspect, there is provided a method for forming a hydrogel comprising the step of adding a cyclic oligosaccharide to a copolymer to form a mixture that undergoes gelation to form the hydrogel, wherein said copolymer comprises an oxygenated polyaromatic alcohol and a poly (alkylene oxide) alkyl ether (meth)acrylate, and wherein the formed hydrogel comprises 1 wt% to 4 wt% of said copolymer and 6 wt% to 14 wt% of said cyclic oligosaccharide.

Definitions

The following words and terms used herein shall have the meaning indicated:

The term "copolymer" refers to a combination of at least two polymers, which polymerize or cross-link with each other to form the copolymer. The copolymer may be a block

copolymer, an alternating copolymer, a random copolymer, a graft copolymer, a brush copolymer, a linear copolymer, a branched copolymer or the like.

The term "hydrogel" is used in the conventional sense to refer to a water-swellable polymeric system that can absorb a substantial amount of water to form an elastic gel.

The term "storage modulus" is used herein as an indicator that characterizes the stiffness of the hydrogel. The storage modulus is the tendency of the hydrogel to be deformed elastically when a force is applied to it.

Claims

1. A hydrogel comprising:

   1 wt% to 4 wt% of a copolymer comprising an oxygenated polyaromatic alcohol and a poly (alkylene oxide) alkyl ether (meth)acrylate; and

   6 wt% to 14 wt% of a cyclic oligosaccharide.

2. The hydrogel of claim 1, wherein said copolymer has a molecular weight in the range of 5,000 g/mol to 500,000 g/mol.

3. The hydrogel of claim 1 or claim 2, wherein said copolymer has a polydispersity of at least 1.

4. The hydrogel of any one of claims 1 to 3, wherein said copolymer has a melting temperature in the range of 32°C to 36°C.

5. The hydrogel of any one of claims 1 to 4, wherein said copolymer has a degradation temperature in the range of 350°C to 370°C.

6. The hydrogel of any one of claims 1 to 5, wherein said copolymer has 5 to 1,000 molecules of poly (alkylene oxide) alkyl ether (meth)acrylate bound to each molecule of the oxygenated polyaromatic alcohol.

7. The hydrogel of any one of claims 1 to 6, wherein said oxygenated polyaromatic alcohol is a lignin or a lignin derivative.

8. The hydrogel of claim 7, wherein said lignin is selected from the group consisting of lignin, steam explosion lignin, acid hydrolysis lignin, lignosulfonate, soda lignin and organosolv lignin.

9. The hydrogel of claim 7 or claim 8, wherein said lignin derivative is selected from the group consisting of lignin esters, lignin ethers, carboxy lignins, hydroxyalkylated lignin, acylated lignin and hydroxyalkoxy lignins.

10. The hydrogel of claim 9, wherein said lignin derivative is selected from the group consisting of lignin acetate, lignin propionate, lignin butyrate, lignin ethyl ether, lignin methyl ether, carboxymethyl lignin, (hydroxyethoxy) lignin, and (hydroxypropoxy) lignin.

11. The hydrogel of any one of claims 1 to 10, wherein said oxygenated polyaromatic alcohol is contained in said copolymer at a weight percentage in the range of about 0.5% to about 90%.

12. The hydrogel of any one of claims 1 to 11, wherein said poly (alkylene oxide) alkyl ether (meth)acrylate is selected from the group consisting of poly (ethylene glycol) methyl ether (meth)acrylate, poly (ethylene glycol) ethyl ether (meth)acrylate, poly (propylene glycol) methyl ether (meth)acrylate, poly (propylene glycol) ethyl ether (meth)acrylate, and mixtures thereof.

13. The hydrogel of any one of claims 1 to 12, wherein said poly (alkylene oxide) alkyl ether (meth)acrylate is a grafted polymer, a block copolymer, a star polymer, a brush polymer or a hyperbranched polymer.

14. The hydrogel of any one of claims 1 to 13, wherein said poly (alkylene oxide) alkyl ether (meth) acrylate contains an average number of alkylene oxide groups in the range of from 2 to 460.

15. The hydrogel of any one of claims 1 to 14, wherein said poly (alkylene oxide) alkyl ether (meth)acrylate has a molecular weight in the range of 200 g/mol to 20,000 g/mol.

16. The hydrogel of any one of claims 1 to 15, further comprising a polymer selected from the group consisting of polyester, polyurethane, polyamide, polyether, polysaccharide, poly(amino acid)s, polypeptides and proteins.

17. The hydrogel of any one of claims 1 to 16, wherein said cyclic oligosaccharide is a cyclodextrin or a derivative thereof.

18. The hydrogel of claim 17, wherein said cyclodextrin or derivative thereof is selected from the group consisting of α-cyclodextrin, β-cyclodextrin, γ-cyclodextrin and methyl-β-cyclodextrin.

19. The hydrogel of any one of claims 1 to 18, having a storage modulus in the range of 0.01Pa to 100GPa.

20. A method for forming a hydrogel comprising the step of adding a cyclic oligosaccharide to a copolymer to form a mixture that undergoes gelation to form the hydrogel, wherein said copolymer comprises an oxygenated polyaromatic alcohol and a poly (alkylene oxide) alkyl ether (meth)acrylate, and wherein the formed hydrogel comprises 1 wt% to 4 wt% of said copolymer and 6 wt% to 14 wt% of said cyclic oligosaccharide.

21. The method of claim 20, wherein said mixture is 1) a copolymer aqueous solution mixed with a cyclic oligosaccharide aqueous solution, or 2) the cyclic oligosaccharide in powder form added to a copolymer aqueous solution.

22. The method of claim 21, wherein said copolymer aqueous solution comprises 0.1 wt% to 80 wt% of said copolymer, based on the weight of the mixture.

23. The method of claim 22, wherein the mixture contains 1 wt% to 50 wt% of the cyclic oligosaccharide, based on the weight of the mixture.