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(54) MEDICAL DEVICES HAVING HOMOGENEOUS CHARGE DENSITY AND METHODS FOR MAKING SAME

MEDIZINISCHE VORRICHTUNGEN MIT HOMOGENER LADUNGSDICHTE UND VERFAHREN ZUR HERSTELLUNG DAVON

DISPOSITIFS MÉDICAUX AYANT UNE DENSITÉ DE CHARGE HOMOGÈNE ET LEURS PROCÉDÉS DE FABRICATION

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WO-A1-2010/039653 **WO-A1-2011/140318**

Description

Field of the Invention

[0001] The present invention relates to ionic silicone hydrogels, and ophthalmic devices formed therefrom, which display desirable tear and polycationic ophthalmic solution component uptake profiles.

Background of the Invention

[0002] It is well known that contact lenses can be used to improve vision. Various contact lenses have been commercially produced for many years. Hydrogel contact lenses are very popular today. These lenses are formed from hydrophilic polymers and copolymers containing repeating units from hydroxyethylmethylacrylate (HEMA). Of these contact lenses formed from copolymers of HEMA and methacrylic acid, are among the most comfortable, and have the lowest rate of adverse events. Contact lenses formed from copolymers of HEMA and MAA, such ACUVUE contact lenses, display substantial amounts of lysozyme uptake (greater than 500 μg) and retain a majority of the uptaken proteins in their native state. However, hydrogel contact lenses generally have oxygen permeabilities that are less than about 30.

[0003] Contact lenses made from silicone hydrogels have been disclosed. These silicone hydrogel lenses have oxygen permeabilities greater than about 60, and many provide reduced levels of hypoxia compared to conventional hydrogel contact lenses. Unfortunately, attempts to add anionic components to silicone hydrogels in the past have produced contact lenses which are not hydrolytically stable and display moduli which increase when exposed to water and heat. Also, while adding ionicity to silicone hydrogels has increased lysozyme uptake, it has also often increased uptake of positively charged components from contact lens multipurpose solutions. One such component is PQ1, a polyquaternium disinfecting compound. Also, many silicone hydrogels have higher than desired contact angles.

[0004] WO 2010/039653 A1 discloses silicone hydrogel contact lenses formed from reactive components comprising a silicone component and an anionic component such as methacrylic acid, and the thermal stability and protein uptake of these.

Summary of the Invention

[0005] The present invention is as described by the attached claims. The disclosure relates to ionic silicone hydrogel polymers and contact lenses formed therefrom displaying desirable performance characteristics, including contact angles of about 70° or less, at least about 50 μg/lens cationic tear component lysozyme uptake, and less than about 10% uptake of at least one polycationic component from an ophthalmic solution with which the polymers or contact lenses are contacted.

[0006] The disclosure also relates to an anionic, silicone hydrogel contact lens comprising in or on said silicone hydrogel at least one statistical copolymer comprising units derived from at least 10 weight% of at least one non-ionic hydrophilic monomer and at least one anionic monomer and wherein said contact lens has a contact angle of about 70° or less, at least about 50 μg/lens lysozyme uptake, and less than about 10% uptake of at least one polycationic component when contacted with 3 mL of an ophthalmic solution comprising said 0.001 wt% polycationic component, 0.56% citrate dihydrate and 0.021 % citric acid monohydrate (wt/wt) The disclosure also relates to a silicone hydrogel formed from a reactive mixture comprising

major polymerizable components comprising at least one reactive silicone-containing component, at least one reactive ionic monomer, optional reactive hydrophilic components and crosslinker; and

minor polymerizable components selected from the group consisting of visibility tint and dyes, UV absorbers, photochromic compounds, pharmaceutical compounds, nutriceutical compounds, and mixtures thereof;

wherein said major polymerizable components comprise a single reactive functionality.

[0007] The disclosure also relates to silicone hydrogels comprising at least one statistical copolymer comprising units derived from at least one anionic monomer and at least 10 weight% of at least one non-ionic hydrophilic monomer.

Detailed Description

[0008] The present invention relates to control of the spatial density and concentration of anionic charges in silicone hydrogel materials and articles made therefrom. It has been found that ionic silicone hydrogel polymers and articles made therefrom may be made having desirably increased tear component uptake (including lysozyme) and low or no uptake of polycationic components from cleaning and care solutions. The silicone hydrogels and articles made therefrom may be made from ionic statistical copolymers or may have associated therewith, at least one non-crosslinked (soluble), ionic statistical copolymer. In the invention the ionic statistical copolymer associates with the lens either through entanglement, association or a combination thereof. For example the contact lens may comprise NVP or PVP as a component in the lens body. In this embodiment, the anionic statistical copolymer forms a persistent association with the lactam moiety of the pyrrolidone. In the invention the anionic statistical copolymer comprises a hydrophobic block on at least one terminus. The hydrophobic block of the anionic statistical copolymer associates with the silicone in the silicone hydrogel contact lens.

[0009] As used herein, a "biomedical device" is any article that is designed to be used while either in or on mammalian tissues or fluid. Examples of these devices include but are not limited to catheters, implants, stents, and ophthalmic devices such as intraocular lenses, inlay lenses and contact lenses.

[0010] As used herein an "ophthalmic device" is any device which resides in or on the eye or any part of the eye, including the cornea, eyelids and ocular glands. These devices can provide optical correction, cosmetic enhancement, vision enhancement, therapeutic benefit (for example as bandages) or delivery of active components such as pharmaceutical and neutraceutical components, or a combination of any of the foregoing. Examples of ophthalmic devices include lenses and optical and ocular inserts, including, but not limited to punctal plugs and the like.

[0011] As used herein, the term "lens" refers to ophthalmic devices that reside in or on the eye. The term lens includes but is not limited to soft contact lenses, hard contact lenses, intraocular lenses, overlay lenses.

[0012] The contact lenses of the present invention are, in one embodiment, made from silicone elastomers or hydrogels, which include but are not limited to silicone hydrogels, and silicone-fluorohydrogels. These hydrogels contain hydrophobic and hydrophilic monomers that are covalently bound to one another in the cured lens.

[0013] As used herein "uptake" means associated in, with or on the lens, deposited in or on the lens. "Percent (%) uptake" of polycationic components means the percent of the polycationic component which associates in, with or on the lens or deposits in or on the lens compared to the total amount of that polycationic component in the ophthalmic solution prior to contact with the silicone hydrogels of the present disclosure.

[0014] As used herein "reactive mixture" refers to the mixture of components (both reactive and non-reactive) which are mixed together and subjected to polymerization conditions to form the ionic silicone hydrogels of the present disclosure. The reactive mixture comprises reactive components such as monomers, macromers, prepolymers, cross-linkers, initiators, diluents and additives such as wetting agents, release agents, dyes, light absorbing compounds such as UV absorbers and photochromic compounds, any of which may be reactive or non-reactive but are capable of being retained within the resulting medical device, as well as pharmaceutical and nutriceutical compounds. It will be appreciated that a wide range of additives may be added based upon the medical device which is made, and its intended use. Concentrations of components of the reactive mixture are given in weight % of all components in the reaction mixture, excluding diluent. When diluents are used their concentrations are given as weight % based upon the amount of all components in the reaction mixture and the diluent.

[0015] As used herein a statistical copolymer is a polymer having at least one segment formed from reactive components having substantially similar reaction rate constants, k for reaction with themselves and with each other. For example, statistical copolymers include crosslinked polymer matrices which are formed from reactive components having the same reactive functionality, polymers formed from reactive components having the same reactive functionality and block copolymers where at least one block is formed from reactive components having the same reactive functionality. Generally, substantially similar reaction rate constants are within about 10%. Reactive components which have the same reactive functionality have substantially similar reaction rate constants.

[0016] As used herein, cationic tear components include cationic proteins including lactoferrin, lysozyme, serum albumin, and secretory immunoglobulin A. Lysozyme is a preferred cationic tear component.

[0017] As used herein, ophthalmic solutions are solutions which are instilled in the eye or are used to condition or clean devices which are placed in the ocular environment. Examples of ophthalmic solutions include eye drops, rewetting drops, contact lens multipurpose solutions, packaging solutions for ophthalmic devices, including contact lenses.

[0018] Contact lens multipurpose solutions frequently contain polycationic components. Polycationic components include positively charged organic compounds, such as cationic water soluble polymeric ammonium salts, such as biguanides, bisbiguanides and polyquaternium containing compounds, also called "polyquats" or PQ compounds. Polyhexamethylene biguanide (PHMB) is a common biguanide used in contact lens, multipurpose, cleaning and care solutions. Examples of water soluble polymeric ammonium salts include polycationic polymers having quartenary ammonium centers. Examples include PQ-1, PQ-42 (poly[oxyethylene(dimethyliminio)ethylene (dimethyliminio)ethylene dichloride]), and the like. Cationic water soluble polymeric tetraalkyl phosphonium salts may also be used in place of the ammonium salts. Non-polymeric cationic organic components having two or more cations such as chlorhexidine (*N*’,*N*’’’’’-hexane-1,6-diylbis[*N*-(4-chlorophenyl)(imidodicarbonimidic diamide)], or CHG), and the like may also be included. Inorganic charged ions, such as sodium ions are not cationic components as defined herein.

[0019] PQ1 is a cationic copolymer having quarternary ammonium ions in its polymer backbone. Specifically PQ1 is poly[(dimethyliminio)-2-butene-1,4-diyl chloride (1:1)], α-[4-[tris(2-hydroxyethyl)ammonio]-2-buten-1-yl]-ω-[tris(2-hydroxyethyl)ammonio]-, chloride (CAS 75345-27-6). Contact lens solutions, including multipurpose solutions and cleaning solutions, generally also contain citrates such as citrate dihydrate and citric acid monohydrate to help prevent PQ1 uptake by contact lenses. However, the addition of anionicity to silicone hydrogel lenses can result in undesirable PQ1 uptake by the lens, even in the presence of citrates. In another embodiment, the present invention further provides desirably low uptake of water soluble polymeric ammonium salts.

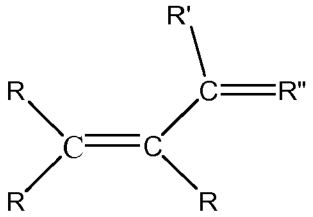
[0020] RAFT refers to reversible addition fragmentation-chain transfer polymerization, a form of "pseudo-living" free radical polymerization.

[0021] Hydrophilic components are components that are at least 10% soluble in water. So, if 10 weight parts of the monomer are combined with 90 weight parts of water, a clear, single phase solution is formed with mixing at room temperature.

[0022] Anionic components are components comprising at least one anionic group and at least one reactive group. Anionic groups are groups which bear a negative charge at neutral pH. Examples of anionic groups include carboxylate groups, phosphates, sulphates, sulphonates, phosphonates, borates, mixtures thereof and the like. In one embodiment the anionic components comprise three to ten carbon atoms, and in another, three to eight carbon atoms. In an embodiment the anionic groups comprise carboxylate groups or sulphonate groups. Anionic components also include ionizable salts of any of the foregoing, for examples salts containing calcium, sodium, lithium, magnesium and mixtures thereof.

[0023] Reactive functionality or groups include those that can undergo chain reaction polymerizations, such as free radical and/or cationic polymerization under polymerization conditions. It is also possible to synthesize silicone copolymers via step reaction polymerization such as polyesters from the reaction of diols and diacids and polyurethanes from the reaction of diols and di-isocyanates or via thiol-ene reactions. In general, polymerizable groups can be classified as activated or unactivated polymerizable groups.

[0024] Activated polymerizable components are those that have at least two double bonds in conjugation:



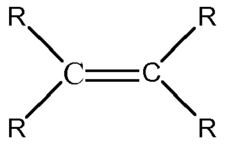
R are independently selected from H, carboxyl groups , ester groups, halides groups, C_1-C_4 alkyl groups, which may be further substituted with carboxylic acid or ester groups. In another embodiment R is selected from H and unsubstituted -C_{1-4} alkyl groups; and in another embodiment from H and methyl, -COOH, -CH2COOH, in another embodiment H and -CH_3;

R' is O or N which is further substituted a group selected from H, C_{1-3} alkyl groups which may be further substituted with hydroxyl groups, carboxyl groups or carboxyester groups; or R' may be an alkenylene, which taken with R" forms a phenyl ring. In one embodiment R' is O or N substituted with H or unsubstituted C_{1-3} alkyl.

R" is O or an alkenylene which when taken with R' forms a phenyl ring.

[0025] Examples of activated polymerizable groups include acrylate or methacrylate esters, itaconic acid esters, fumaric or maleic acid esters, acrylamides or methacrylamides, or styrenes.

[0026] Unactivated polymerizable groups have a carbon-carbon double bond, but do not have a second double bond in conjugation:



in which each R may be H, C_1-C_4 alkyl groups which may be unsubstituted or substituted with hydroxyl, carboxy, carboxyester, Cl, Br, O, or $N(R^2)COR^3$, R^2 is H or COR^3, unsubstituted C1-3 alkyl, R^3 H or unsubstituted C1-3, and Rx and Ry may together be propylene, O may be substituted with C1-3 alkyl or CORx provided that the atom bonded to the carbon-carbon bond is not itself doubly or triply bonded. Examples of unactivated polymerizable groups include vinyl lactams, vinyl amides, vinyl carbonates, vinyl carbamates, allyl ethers, allyl alcohols and the like.

[0027] Non-limiting examples of free radical reactive groups include (meth)acrylates, styryls, vinyls, vinyl ethers, C_{1-6}alkyl(meth)acrylates, (meth)acrylamides, C_{1-6}alkyl(meth)acrylamides, N-vinyllactams, N-vinylamides, C_{2-12}alkenyls, C_{2-12}alkenylphenyls, C_{2-12}alkenylnaphthyls, C_{2-6}alkenylphenylC_{1-6}alkyls, O-vinylcarbamates and O-vinylcarbonates. Non-limiting examples of cationic reactive groups (groups that can polymerize under cationic polymerization conditions) include vinyl ethers or epoxide groups and mixtures thereof. In one embodiment the reactive groups comprises (meth)acrylate, acryloxy, (meth)acrylamide, and mixtures thereof.

[0028] Any chemical name preceded by (meth), for example (meth)acrylate, includes both the unsubstituted and methyl substituted compound.

[0029] A statistical copolymer is formed between reactive comonomers, for example A and B, when their reactivity ratios, r_A and r_B, approximate each other and approach unity. The "statistical" or "non-statistical" copolymerization of these two monomers is characterized by the relative mole fractions of monomers A and B that incorporate into the backbone of the copolymer as it is undergoing polymerization. The mole fraction of monomer A, F_A, incorporated into a copolymer of A and B, for example, is predicted by the Mayo-Lewis Equation:

$$F_A = \frac{r_A f_A^2 + f_A f_B}{r_A f_A^2 + 2 f_A f_B + r_B f_B^2}$$

Where $r_A = \frac{k_{AA}}{k_{AB}}$, $r_B = \frac{k_{BB}}{k_{BA}}$, and f_A and f_B are the relative mole fractions of A and B. The reactivity ratios, r_A and r_B, are defined by four propagation rate constants, k_{AA}, k_{AB}, k_{BA}, and k_{BB}. For a propagating copolymer in a comonomer mixture of A and B, there are four possible radical addition scenarios that yield four distinct propagation rate constants:

$$\sim\!\!\sim M_A^{\bullet} + M_A \xrightarrow{k_{AA}} \sim\!\!\sim M_A\text{-}M_A^{\bullet}$$

$$\sim\!\!\sim M_A^{\bullet} + M_B \xrightarrow{k_{AB}} \sim\!\!\sim M_A\text{-}M_B^{\bullet}$$

$$\sim\!\!\sim M_B^{\bullet} + M_A \xrightarrow{k_{BA}} \sim\!\!\sim M_B\text{-}M_A^{\bullet}$$

$$\sim\!\!\sim M_B^{\bullet} + M_B \xrightarrow{k_{BB}} \sim\!\!\sim M_B\text{-}M_B^{\bullet}$$

[0030] Generally, the relative values of r_A and r_B, the mole fractions of both monomers, and the extent of conversion of the copolymerization are the major factors which dictate the microstructure of the resultant copolymer. In general there are limiting cases for r_A and r_B that apply specifically to the invention disclosed herein. In cases where r_A and r_B are equal and approach unity (*e.g.* $r_A = r_B \approx 1$) the copolymerization is considered to be "random" or "statistical," *i.e.* there is an equal probability that monomer A will add to itself and to monomer B, and monomer B will add to itself and monomer A with equal probability also. In one embodiment "similar" reactivity ratios are those for which the reactivity ratios of the fastest and slowest reactive components in the reactive mixture are within 25% of each other, and in another embodiment within about 10% of each other, and in another embodiment within about 5% of each other. In some embodiments minor reactive additives, such as reactive dyes or UV absorbers can have reactivity ratios which are greater than the herein disclosed ranges. The reactivity ratios may be determined by measuring the relative depletion of monomer A and B from the polymerization solution and the relative incorporation of A and B into the resultant copolymer. This measurement is taken at low total monomer conversion, i.e. around 10-20 %, and is repeated across a range of initial monomer compositions between 1-99 % A or 99-1 % B.

[0031] In another embodiment, the random or statistical copolymers are formed from charged monomers and other monomers comprising the same reactive double-bonds (anionic charge-bearing acrylamido-monomers being paired with other acrylamido-comonomers or anionic charge-bearing methacrylic-monomers being paired with other methacrylate-comonomers). As shown by the Examples herein, the consumption of charge-bearing monomers with other monomers that contain the same reactive functionality produce lenses which display the desired selective uptake of cationic tear components, such as lysozyme over polycationic components, such as PQ1. Reactive mixtures comprising reactive components having the same reactive functionality and similar reactivity ratios (that approach unity), which produce the homogeneous distribution of charge across the surface and throughout the bulk of the lens.

[0032] Where $r_A = r_B \approx 0$, the probabilities of monomers A and B adding to themselves is very low. This results in the formation of alternating copolymers of A and B, and lens materials having the desired distribution of charge throughout the lens and the desired selective uptake of cationic tear components over polycationic components.

[0033] Where $r_A > 1 > r_B$, statistical copolymers of the present invention are not formed. In this case early in the polymerization, monomer A is consumed at a higher rate than monomer B. At this early point in the copolymerization, copolymers that are formed are very rich in monomer A. As the polymerization progresses and monomer A is depleted over monomer B, thus changing the relative mole fractions in favor of monomer B, the copolymer microstructure shifts from being rich in monomer A to rich in monomer B. This occurs until all or most of monomer A is consumed, at which point the polymer that is formed is completely or mostly composed of monomer B. This is also known to those skilled in the art as "compositional drift." In a comparative example of this invention, an anionic acrylamido-monomer is copolymerized in a mixture of methacrylates and other acrylamides to make a contact lens or medical device. In this case, it is believed that the methacrylates are consumed at a much higher rate, compared to the acrylamido-monomers early in the polymerization. This continues until all or most of the methacrylates are consumed, after which point the acrylamido-monomers are consumed and the polymerization reaches 100 % conversion. Because the anionic charge-bearing acrylamido-monomer has a much higher probability of being consumed later in the reaction, the charge in and on the bulk and surface of the substrate is not homogeneously distributed throughout the polymer bulk. This leads to a significant amount of PQ1 uptake as well as lysozyme, which is undesirable.

[0034] When $r_A = r_B > 1$, blocky-type copolymers are formed. In this case monomer A has a high probability of adding to itself over monomer B and monomer B has a high probability of adding to itself over monomer A. In extreme cases, where A would rarely add to B and *vice versa, i.e.* where $r_A = r_B >> 1$, formation of a mixture of homopolymers is anticipated. These cases are believed to produce a heterogeneous distribution of charge in and on the resulting substrate.

[0035] It has been found that by selecting the components of the reactive mixture such that reactivity rates are substantially matched, statistical copolymers can be made wherein the units from the anionic monomers are randomly distributed throughout either the polymer or at least one segment of the polymer, depending upon the embodiment of the present invention. The random distribution of negative charge throughout the polymer is believed to provide a delocalization of charge, which provides increased uptake by the polymer of beneficial proteins such as lysozyme, but low uptake of positively charged components in contact lens solutions, including polyquartemium salts, such as, but not limited to PQ1.

[0036] Thus, in one embodiment the non-ionic hydrophilic monomer and the anionic monomer are either both activated or both unactivated. In another embodiment the reactive functionality for both the non-ionic hydrophilic monomer and the anionic monomer are the same, for example both the non-ionic hydrophilic monomer and the anionic monomer are both are methacrylates. In another embodiment both the non-ionic hydrophilic monomer and the anionic monomer are methacrylamides. Non-limiting examples of such combinations are included in the Examples below.

[0037] Examples of suitable anionic components include reactive carboxylic acids, including alkylacrylic acids, such as (meth)acrylic acid, acrylic acid, itaconic acid, crotonic acid, cinnamic acid, vinylbenzoic acid, fumaric acid, maleic acid, monoesters of furmaric acid, maelic acid and itaconic acid; 3-acrylamidopropionic acid, 4-acrylamidobutanoic acid, 5-acrylamidopentanoic acid, N-vinyloxycarbonyl-α-alanine, N-vinyloxycarbonyl-β-alanine (VINAL), 2-vinyl-4,4-dimethyl-2-oxazolin-5-one (VDMO), reactive sulphonate salts, including sodium-2-(acrylamido)-2-methylpropane sulphonate, 3-sulphopropyl (meth)acrylate potassium salt, 3-sulphopropyl (meth)acrylate sodium salt, bis 3- sulphopropyl itaconate di sodium, bis 3- sulphopropyl itaconate di potassium, vinyl sulphonate sodium salt, vinyl sulphonate salt, styrene sulphonate, 2-sulphoethyl methacrylate and mixtures thereof and the like. In one embodiment the anionic component is selected from reactive carboxylic acids, in another from methacrylic acid and N-vinyloxycarbonyl alanine. In another embodiment, where the reactive monomers comprise acrylamido reactive groups the anionic monomer comprises an acrylamide acid, such as 3-acrylamidopropionic acid, 4-acrylamidobutanoic acid, 5-acrylamidopentanoic acid, 2-acrylamido-2-methylpropane sulphonic acid, salts of said acrylamido acids and combinations thereof. Suitable salts include ophthalmically compatible salts including sodium, potassium and calcium salts.

[0038] It has been surprisingly found that the acrylamido sulphonic acid or acrylamido sulphonic acid salts are compatible with the all acrylamide formulations of the present invention. The acrylamido sulphonic acid or acrylamido sulphonic acid salts are generally too polar to be soluble in silicone hydrogel reactive mixtures, even at the low molar concentrations disclosed herein. However, when the single reactive functionality is methacrylamide acrylamido sulphonic acid or acrylamido sulphonic acid salt may be directly incorporated into the reactive mixture in amounts up to about 5 mole%, in some embodiments up to about 3 mol%, and in other embodiments between about 0.1 to about 2 mol%.

[0039] In another embodiment the reactive components comprise methacrylate groups and the ionic component comprises methacrylic acid. It is understood that these monomers may be copolymerized in a non-ionic (ester) form, and then deprotonated or hydrolyzed to form ionic groups in the final product.

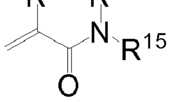
[0040] Those of skill in the art will understand that the foregoing anionic monomers are selected based upon the functionality of the other reactive components. For example, when the major polymerizable components comprise acrylamide reactive functionality the anionic monomer may be 3-acrylamidopropionic acid, 4-acrylamidobutanoic acid, 5-acrylamidopentanoic acid, sodium-2-(acrylamido)-2-methylpropane sulphonate, 2-acrylamido-2-methylpropane sulfonic acid and combinations thereof.

[0041] When the major polymerizable components comprise (meth)acrylate functionality the anionic monomer may be (meth)acrylic acid, itaconic acid, crotonic acid, cinnamic acid, fumaric acid, maleic acid, monoesters of furmaric acid, 3-sulphopropyl (meth)acrylate potassium salt, 3-sulphopropyl (meth)acrylate sodium salt, bis 3-sulphopropyl itaconate di sodium, bis 3- sulphopropyl itaconate di potassium, sulphoethyl methacrylate, and mixtures thereof. In another embodiment the major polymerizable components comprise (meth)acrylate functionality, and the anionic monomer may be (meth)acrylic acid, 3-sulphopropyl (meth)acrylate potassium salt, 3-sulphopropyl (meth)acrylate sodium salt, sulphoethyl methacrylate, and mixtures thereof.

[0042] When the major polymerizable components comprise vinyl functionality the anionic monomer may be N-vinyloxycarbonyl-α-alanine, N-vinyloxycarbonyl-β-alanine, 2-vinyl-4,4-dimethyl-2-oxazolin-5-one, vinyl sulphonate sodium salt, vinyl sulphonate salt, and mixtures thereof.

[0043] Suitable non-ionic hydrophilic monomers include N,N-dimethyl acrylamide (DMA), 2-hydroxyethyl methacrylate (HEMA), glycerol methacrylate, 2-hydroxyethyl methacrylamide, polyethyleneglycol monomethacrylate, N-vinyl amides, N-vinyl lactams (e.g. NVP), N-vinyl-N-methyl acetamide, N-vinyl-N-ethyl acetamide, N-vinyl-N-ethyl formamide, N-vinyl formamide. Vinyl carbonate or vinyl carbamate monomers, such as those disclosed in U.S. Patents No. 5,070,215, and the hydrophilic oxazolone monomers disclosed in U.S. Patents No. 4,910,277 may also be used.

[0044] The hydroxyl-containing (meth)acrylamide monomers of Formula c0, disclosed in US 2011-0230589 A1 may also be used:



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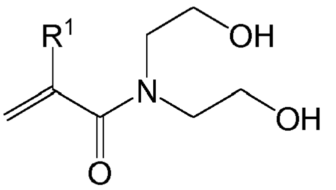
wherein, R^1 is hydrogen or methyl; at least one of R^{14} and R^{15} is substituted with a C1-C20 alkyl substituted with at least one hydroxyl group, with the proviso that when i) one of R^{14} and R^{15} is hydrogen, ii) the other of R^{14} and R^{15} is a C1-C20 alkyl group substituted with two or more hydroxyl groups. In one embodiment, the non-silicone (meth)acrylamide monomer comprises two or more hydroxyl groups in the molecule. In some embodiments R1 is a hydrogen atom and at least one of R^{14} and R^{15} is selected from hydrogen, optionally substituted C1-C20 alkyl group, or optionally substituted C6-C20 aryl group with the proviso that the total number of hydroxyl groups in R^{14} and R^{15} is two or more. In one embodiment R^{14} and R^{15} is are independently selected from C1-C10 alkyl group which may be substituted with at least one more hydroxyl group, and in other embodiments C1-C6 alkyl group which may be substituted with at least one more hydroxyl group, so long as the hydrophilic (meth)acrylamide meets the proviso above.

[0045] Examples of R^{14} and R^{15} include hydrogen atoms, methyl groups, ethyl groups, propyl groups, n-propyl groups, i-propyl groups, n-butyl groups, s-butyl groups, t-butyl groups, n-pentyl groups, i-pentyl groups, s-pentyl groups, neopentyl groups, hexyl groups, heptyl groups, octyl groups, nonyl groups, decyl groups, dodecyl groups, eicosyl groups, phenyl groups, naphthyl groups, 2-hydroxyethyl groups, 2-hydroxypropyl groups, 3-hydroxypropyl groups, 2,3-dihydroxypropyl groups, 4-hydroxy butyl groups, 2-hydroxy-1,1-bis(hydroxymethyl) ethyl groups, 2-hydroxymethylphenyl groups, 3-hydroxymethylphenyl groups, 4-hydroxymethylphenyl groups and the like. These alkyl and hydroxyalkyl groups can be straight or branched. A particularly preferable example of a non-silicone type (meth)acrylamide monomer containing two or more hydroxyl groups in the molecule include the monomers expressed by the following general formulae (c1) through (c3).

[FORMULA 10]



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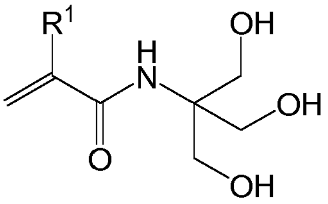

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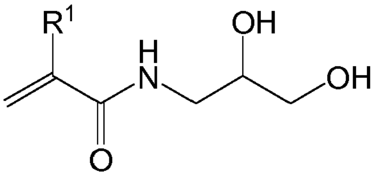
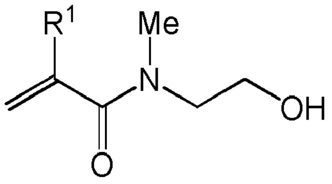


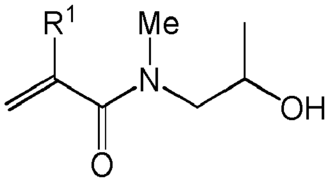
(c3)

In chemical formulae (c1) through (c3), R^1 independently represents a hydrogen atom or a methyl group.

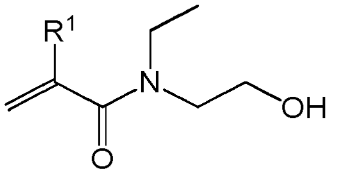
[0046] In another embodiment, the hydroxyl-containing (meth)acrylamide monomer comprises one hydroxyl group and no amide hydrogen in the molecule. In chemical formula (c0) of this embodiment, R^1 represents methyl and R^{14} and R^{15} are independently selected from optionally substituted C1-C20 alkyl group, or optionally substituted C6-C20 aryl group with the proviso that one of R^{14} and R^{15} is substituted with at least one hydroxyl group. Examples of R^{14} and R^{15} include methyl groups, ethyl groups, propyl groups, n-propyl groups, i-propyl groups, n-butyl groups, s-butyl groups, t-butyl groups, n-pentyl groups, i-pentyl groups, s-pentyl groups, neopentyl groups, hexyl groups, heptyl groups, octyl groups, nonyl groups, decyl groups, dodecyl groups, eicosyl groups, phenyl groups, naphthyl groups, 2-hydroxyethyl groups, 2-hydroxypropyl groups, 3-hydroxypropyl groups, 4-hydroxy butyl groups, 2-hydroxymethylphenyl groups, 3-hydroxymethylphenyl groups, 4-hydroxymethylphenyl groups and the like. These alkyl groups can be straight or branched. Examples of hydroxyl-containing acrylamide monomer of this embodiment include the monomers expressed by the following general formulae (c11) through (c13).



(c11)



(c12)



(c13)

In chemical formulae (c11) through (c13), R^1 independently represents a methyl group.

[0047] In some embodiments acrylamide monomer comprising one hydroxyl group and one amide hydrogen in the molecule may be used. Examples of a mono-hydroxyl functionalized acrylamide monomer include N-(mono-hydroxyl substituted C1-C20 alkyl)acrylamide and N-(mono-hydroxyl substituted C6-C20 aryl)acrylamide. More specific examples include N-(2-hydroxyethyl)acrylamide, N-(2-hydroxypropyl)acrylamide, N-(3-hydroxypropyl)acrylamide, N-(2-hydroxybutyl)acrylamide, N-(3-hydroxybutyl)acrylamide, N-(4-hydroxy butyl)acrylamide, N-(2-hydroxymethylphenyl)acrylamide, N-(3-hydroxymethylphenyl)acrylamide, N-(4-hydroxymethylphenyl)acrylamide and the like. In some embodiments, N-(mono-hydroxyl substituted C2-C4 alkyl)acrylamide and particularly N-(2-hydroxyethyl)acrylamide may be preferred.

[0048] The amount of the anionic monomer is also important. Even when a desirable charge distribution has been achieved, if the concentration of the anionic monomer is too high, undesirable PQ-1 uptake may occur. Thus, in embodiment, where the anionic monomer is a component of a reusable silicone hydrogel contact lens, the anionic monomer may be included in amounts up to about 5 mol%, in some embodiments between about 0.1 and about 5 mol%, between about 0.1 and about 4 mol%, and in other embodiments between about 0.2 and about 4 mol%. In embodiments where the contact lens is worn for only a single day and then thrown away, higher amounts of the anionic monomer may be included. The upper limit for the anionic monomer in these embodiments may be selected to provide the desired level of lysozyme or other team components, and a water content of less than about 70% water, in some embodiments less than 70% water, and in others less than about 65% water.

[0049] The anionic monomer and non-ionic hydrophilic monomer may be copolymerized (either alone or with additional components) to form a water soluble, uncrosslinked polymer or may be included in a silicone hydrogel reaction mixture and cured to form the silicone hydrogel contact lens.

[0050] When the anionic monomer and non-ionic, hydrophilic monomer are copolymerized to form an uncrosslinked statistical copolymer, the anionic monomer is present in the uncrosslinked statistical copolymer in amounts between about 20 to about 80 mol%, and in some embodiments between about 20 to about 60 mol%. The non-ionic, hydrophilic monomer may be present in amounts between about 80 to about 20 mol% and in some embodiments between about 80 to about 40 mol%. If the polymer contains a hydrophobic segment or block, as described below, these mol% are based upon the hydrophilic segment of the polymer only.

[0051] The hydrophilic segment of the uncrosslinked statistical copolymers of the present invention can have a degree of polymerization of at least about 300.

[0052] The uncrosslinked statistical copolymers may be formed by a number of methods including, but not limited to, step growth polymerization, such as thiol-ene chemistry, and chain reaction polymerization, such as free radical polymerization and RAFT.

[0053] The uncrosslinked statistical copolymer further comprises a hydrophobic block on at least one terminal end of the uncrosslinked statistical copolymer. In the disclosure, the hydrophobic block may be a hydrocarbon block, a siloxane block, or any other block which is capable of associating with the silicone hydrogel contact lens. In another case the uncrosslinked statistical copolymer has a hydrophobic block which is capable of associating with another polymeric biomedical device such as a stent, a rigid contact lens, a catheter, stent or other implant.

[0054] In the invention, the hydrophobic block comprises polydialkylsiloxane, polydiarylsiloxane and mixtures thereof. The alkyls may be independently selected from C_1-C_4 alkyl, and in one embodiment the hydrophobic block comprises polydimethylsiloxane or polydiethylsiloxane, either of which may be terminated by a C_{1-12} alkyl, C_1-C_4 alkyl, aryl or in some embodiments methyl or n-butyl.

[0055] The hydrophobic block may comprise between about 6 and about 200 siloxy units, between about 6 and about 60 siloxy units, 6 and about 20 siloxy units, 6-15 siloxy units and 6 to 12 siloxy units.

[0056] The uncrosslinked, statistical copolymers may be dissolved in solutions which swell the medical device and contacted with the medical device. In one case where the device is a silicone hydrogel contact lens the uncrosslinked, statistical copolymers are dissolved in water or an aqueous solution and contacted with the contact lens during processing, packaging or cleaning or storage of the lens. For example the uncrosslinked, statistical copolymers may be incorporated into a hydration or packaging solution or may be included in a multipurpose or cleaning solution which is used by the contact lens wearer.

[0057] The amount of uncrosslinked, statistical copolymers included in the solutions will depend in part on the concentration of the anionic monomer in the uncrosslinked, statistical copolymers. For example, uncrosslinked, statistical copolymers containing 30 mol% anionic monomer can be added in higher amounts than uncrosslinked, statistical copolymers having 80 mol% anionic monomer, as is shown the Examples. It is desirable to balance the concentration of anionic monomer in the uncrosslinked, statistical copolymers with the concentration of uncrosslinked, statistical copolymers in the solution to achieve the desired levels of lysozyme and PQ1 uptake. Concentrations of uncrosslinked, statistical copolymers of up to about 2000 ppm, and in some cases between about 20 ppm and 2000ppm and in other cases between about 50 and about 1500 ppm are desirable.

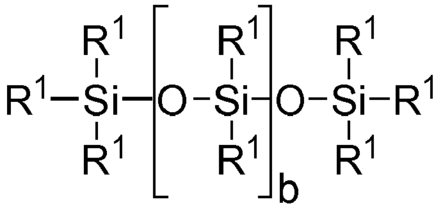
[0058] In another aspect of the disclosure the anionic monomer and the non-ionic hydrophilic monomer are included in the silicone hydrogel reactive mixture to form a silicone hydrogel polymer having a homogeneously distributed anionic charge throughout the polymer. The resulting contact lens has a contact angle of less than about 70°, less than about 50° and in some cases less than about 30° all as measured by sessile drop.

[0059] Substantially all of the polymerizable components in the reaction mixture have the same reactive functionality. Non-reactive components, such as wetting agents may also be present. Contact lens formulations may contain small amounts of components, such as, but not limited to handling tints and UV absorbers, which because of their small concentration, do not need to have the same reactive functionality. Generally, the concentration of reactive components in the reaction mixture which have different functionality should be limited to less than about 0.5 mol%. Non-reactive components, such as non-reactive wetting agents may be present in greater amounts (up about 15 weight%, and in some cases up to about 20 weight%) as they do not participate in the reaction.

[0060] In the disclosure the anionic monomer is present in the reactive mixture in concentrations in amounts up to about 5 mol%, in some cases between about 0.1 and about 5 mol%, between about 0.1 and about 4 mol%, and in other cases between about 0.2 and about 4 mol%. The non-ionic hydrophilic monomer is present in amounts of at least about 10 wt%, and in some cases between about 10 wt% and about 70 wt%, between about 20 and about 60% and in other cases, between about 20 and about 50 weight %.

[0061] The reaction mixture further comprises at least one silicone-containing component. A silicone-containing component is one that contains at least one [-Si-O-] group, in a monomer, macromer or prepolymer. In one case, the Si (silicon) and attached O are present in the silicone-containing component in an amount greater than 20 weight percent, and in another case greater than 30 weight percent of the total molecular weight of the silicone-containing component. Useful silicone-containing components comprise polymerizable functional groups such as (meth)acrylate, (meth)acrylamide, N-vinyl lactam, N-vinylamide, and styryl functional groups. Examples of silicone-containing components which are useful in this disclosure may be found in U.S. Pat. Nos. 3,808,178; 4,120,570; 4,136,250; 4,153,641; 4,740,533; 5,034,461 and 5,070,215, and EP080539. These references disclose many examples of olefinic silicone-containing components.

[0062] Suitable silicone-containing components include compounds of Formula I



$$R^1-\overset{\displaystyle R^1}{\underset{\displaystyle R^1}{Si}}-\left[O-\overset{\displaystyle R^1}{\underset{\displaystyle R^1}{Si}}\right]_b-O-\overset{\displaystyle R^1}{\underset{\displaystyle R^1}{Si}}-R^1$$

where R^1 is independently selected from monovalent reactive groups, siloxane chain, monovalent alkyl groups, or monovalent aryl groups. The monovalent alkyl and aryl groups further comprise functionality selected from hydroxy, amino, oxa, carboxy, alkyl carboxy, alkoxy, amido, carbamate, carbonate, halogen or combinations thereof; and monovalent siloxane chains comprising 1-100 Si-O repeat units which may further comprise functionality selected from alkyl, hydroxy, amino, oxa, carboxy, alkyl carboxy, ether, amido, carbamate, halogen or combinations thereof; where b = 0 to 500, where it is understood that when b is other than 0, b is a distribution having a mode equal to a stated value;

wherein at least one R^1 comprises at least one monovalent reactive group, and in some cases between one and 3 R^1 comprise monovalent reactive groups.

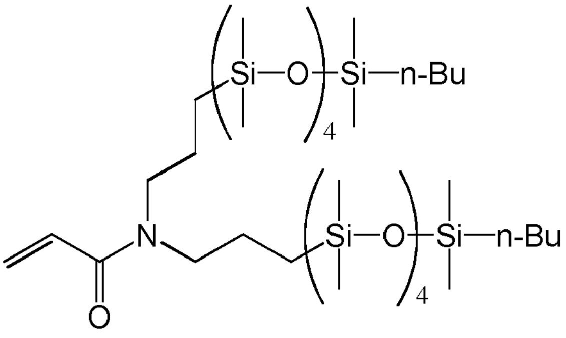
[0063] As used herein "monovalent reactive groups" are groups that can undergo polymerization such as free radical, anionic and/or cationic polymerization. Non-limiting examples of free radical reactive groups include (meth)acrylates, styryls, vinyls, vinyl ethers, substituted or unsubstituted $C_{1\text{-}6}$alkyl(meth)acrylates, (meth)acrylamides, substituted or unsubstituted $C_{1\text{-}6}$alkyl(meth)acrylamides, N-vinyllactams, N-vinylamides, $C_{2\text{-}12}$alkenyls, $C_{2\text{-}12}$alkenylphenyls, $C_{2\text{-}12}$alkenylnaphthyls, $C_{2\text{-}6}$alkenylphenyl$C_{1\text{-}6}$alkyls, O-vinylcarbamates and O-vinylcarbonates. Suitable substituents on said C1-6 alkyls include ethers, hydroxyls, carboxyls, halogens and combinations thereof. Non-limiting examples of cationic reactive groups include vinyl ethers or epoxide groups and mixtures thereof. In one embodiment the free radical reactive groups comprises (meth)acrylate, acryloxy, (meth)acrylamide, and mixtures thereof.

[0064] Suitable monovalent alkyl and aryl groups include unsubstituted monovalent C_1 to C_{16}alkyl groups, C_6-C_{14} aryl groups, such as substituted and unsubstituted methyl, ethyl, propyl, butyl, 2-hydroxypropyl, propoxypropyl, polyethyleneoxypropyl, combinations thereof and the like.

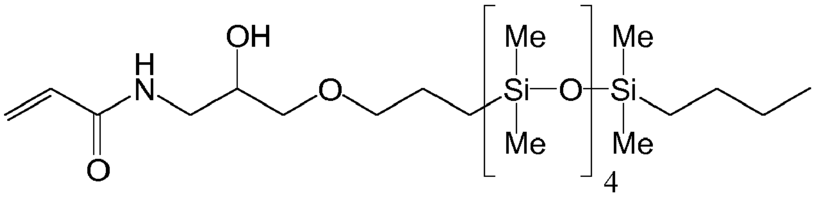
[0065] In one case R^1 is selected from C_{1-6}alkyl(meth)acrylates, and C_{1-6}alkyl(meth)acrylamides, which may be unsubstituted or substituted with hydroxyl, alkylene ether or a combination thereof In another case R^1 is selected from propyl(meth)acrylates and propyl (meth)acrylamides, wherein said propyl may be optionally substituted with hydroxyl, alkylene ether or a combination thereof.

[0066] In one case b is zero, one R^1 is a monovalent reactive group, and at least 3 R^1 are selected from monovalent alkyl groups having one to 16 carbon atoms, and in another case from monovalent alkyl groups having one to 6 carbon atoms. Non-limiting examples of silicone components of this case include 2-methyl-,2-hydroxy-3-[3-[1,3,3,3-tetramethyl-1-[(trimethylsilyl)oxy]disiloxanyl]propoxy]propyl ester ("SiGMA"), 2-hydroxy-3-methacryloxypropyloxypropyl-tris(trimethylsiloxy)silane, 3-methacryloxypropyltris(trimethylsiloxy)silane ("TRIS"), 3 -methacryloxypropylbis(trimethylsiloxy)methylsilane and 3-methacryloxypropylpentamethyl disiloxane.

[0067] In another case, b is 2 to 20, 3 to 15 or in some cases 3 to 10; at least one terminal R^1 comprises at least one monovalent reactive group and the remaining R^1 are selected from monovalent alkyl groups having 1 to 16 carbon atoms, and in another case from monovalent alkyl groups having 1 to 6 carbon atoms. In yet another case, b is 3 to 15, one terminal R^1 comprises a monovalent reactive group selected from substituted or unsubstituted C_{1-6}alkyl(meth)acrylates, substituted or unsubstituted C_{1-6}alkyl(meth)acrylamides, the other terminal R^1 comprises a monovalent alkyl group having 1 to 6 carbon atoms and the remaining R^1 comprise monovalent alkyl group having 1 to 3 carbon atoms. Non-limiting examples of silicone components of this case include (mono-(2-hydroxy-3-methacryloxypropyl)-propyl ether terminated, n-butyl terminated polydimethylsiloxane (400-1000 MW)) ("OH-mPDMS"), monomethacryloxypropyl terminated mono-n-butyl terminated polydimethylsiloxanes (800-1000 MW), ("mPDMS"), N-(2,3-dihydroxypropane)-N'-(propyl tetra(dimethylsiloxy) dimethylbutylsilane)acrylamide, and methacryamide silicones of the following formulae (s1) through (s6);



(s1)



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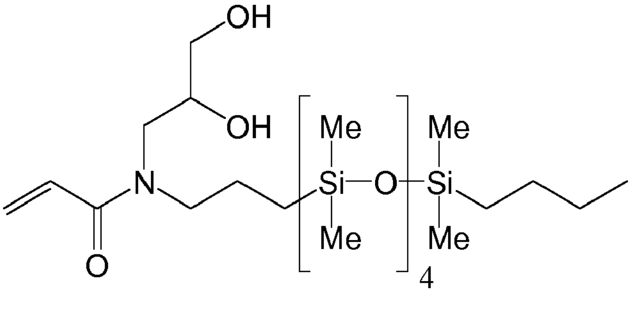
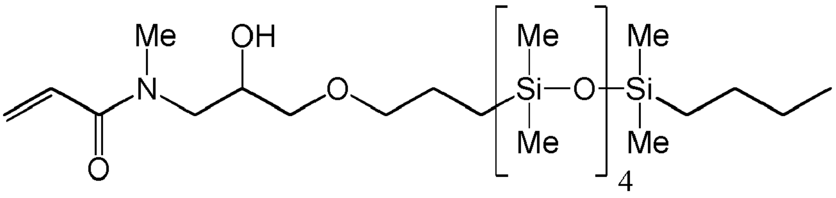
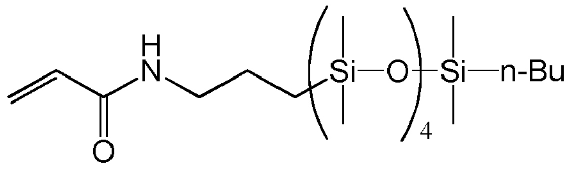


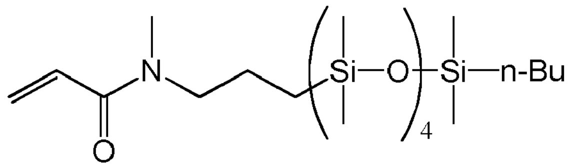
(s3)



(s4)



(s5)

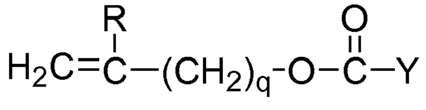


(s6)

[0068] In another case b is 5 to 400 or from 10 to 300, both terminal R^1 comprise monovalent reactive groups and the remaining R^1 are independently selected from monovalent alkyl groups having 1 to 18 carbon atoms which may have ether linkages between carbon atoms and may further comprise halogen.

[0069] In another case, one to four R^1 comprises an allyl or vinyl carbonate or carbamate of the formula:

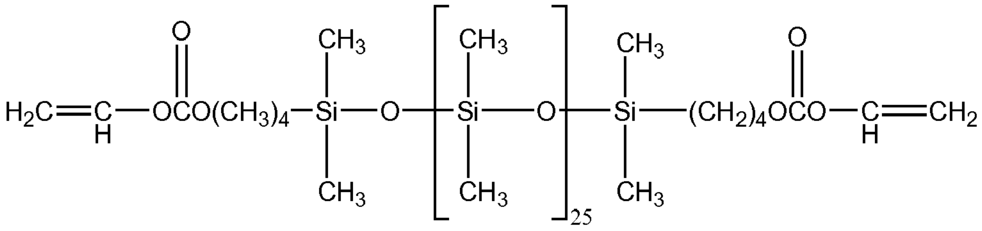
Formula XII



$$H_2C=\overset{R}{\overset{|}{C}}-(CH_2)_q\text{-}O-\overset{O}{\overset{\|}{C}}-Y$$

wherein: Y denotes O-, S- or NH-;
R denotes, hydrogen or methyl; d is 1, 2, 3 or 4; and q is 0 or 1.

[0070] The silicone-containing carbonate or carbamate monomers specifically include: 1,3-bis[4-(vinyloxycarbonyloxy)but-4-(vinyloxycarbonyloxy)but-1 -yl]tetramethyl-disiloxane; 3-(vinyloxycarbonylthio) propyl-[tris (trimethylsiloxy)silane]; 3-[tris(trimethylsiloxy)silyl] propyl allyl carbamate; 3-[tris(trimethylsiloxy)silyl] propyl vinyl carbamate; trimethylsilylethyl vinyl carbonate; trimethylsilylmethyl vinyl carbonate, and



$$H_2C=\underset{H}{C}-O\overset{O}{\overset{\|}{C}}O(CH_3)_4-\underset{CH_3}{\overset{CH_3}{Si}}-O-\left[\underset{CH_3}{\overset{CH_3}{Si}}-O\right]_{25}-\underset{CH_3}{\overset{CH_3}{Si}}-(CH_2)_4O\overset{O}{\overset{\|}{C}}O-\underset{H}{C}=CH_2$$

[0071] In another case, where an acrylamide system is used, the (meth)acrylamide silicones of US2011/0237766 may be used with acrylamide hydrophilic monomers such as DMA and HEAA and acrylamide anionic monomers such as 3-acrylamidopropanoic acid (ACA1) or 5-acrylamidopentanoic acid (ACA2).

[0072] Where biomedical devices with modulus below about 200 are desired, only one R^1 shall comprise a monovalent reactive group and no more than two of the remaining R^1 groups will comprise monovalent siloxane groups.

[0073] In one embodiment, where a silicone hydrogel lens is desired, the lens of the present invention will be made from a reactive mixture comprising at least about 20 weight % and in some embodiments between about 20 and 70%wt silicone-containing components based on total weight of reactive monomer components from which the polymer is made.

[0074] Another class of silicone-containing components includes polyurethane macromers of the following formulae:

Formulae XIII-XV

$(*D*A*D*G)_a *D*D*E^1$;

$E(*D*G*D*A)_a *D*G*D*E^1$ or;

$E(*D*A*D*G)_a *D*A*D*E^1$

wherein:

D denotes an alkyl diradical, an alkyl cycloalkyl diradical, a cycloalkyl diradical, an aryl diradical or an alkylaryl diradical having 6 to 30 carbon atoms,

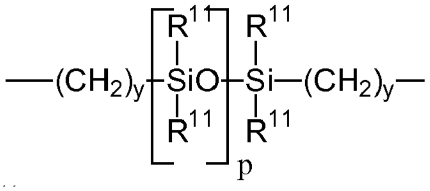
G denotes an alkyl diradical, a cycloalkyl diradical, an alkyl cycloalkyl diradical, an aryl diradical or an alkylaryl diradical having 1 to 40 carbon atoms and which may contain ether, thio or amine linkages in the main chain;

* denotes a urethane or ureido linkage;

$_a$ is at least 1;

[0075] A denotes a divalent polymeric radical of formula:

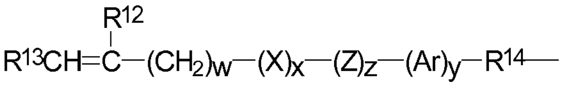
Formula XVI



$$-(CH_2)_y-\left[\overset{R^{11}}{\underset{R^{11}}{Si}}O\right]_p-\overset{R^{11}}{\underset{R^{11}}{Si}}-(CH_2)_y-$$

[0076] R^{11} independently denotes an alkyl or fluoro-substituted alkyl group having 1 to 10 carbon atoms which may contain ether linkages between carbon atoms; y is at least 1; and p provides a moiety weight of 400 to 10,000; each of E and E^1 independently denotes a polymerizable unsaturated organic radical represented by formula:

Formula XVII

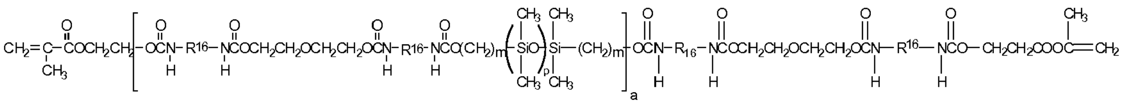


$$R^{13}CH=\overset{R^{12}}{C}-(CH_2)_w-(X)_x-(Z)_z-(Ar)_y-R^{14}-$$

wherein: R^{12} is hydrogen or methyl; R^{13} is hydrogen, an alkyl radical having 1 to 6 carbon atoms, or a -CO-Y-R^{15} radical wherein Y is -O-,Y-S- or -NH-; R^{14} is a divalent radical having 1 to 12 carbon atoms; X denotes -CO- or -OCO-; Z denotes -O- or -NH-; Ar denotes an aromatic radical having 6 to 30 carbon atoms; w is 0 to 6; x is 0 or 1; y is 0 or 1; and z is 0 or 1.

[0077] In one case the silicone-containing component comprises a polyurethane macromer represented by the following formula:

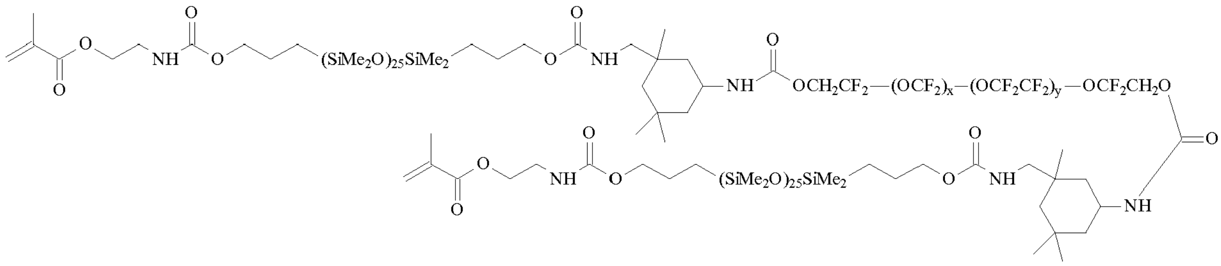
Formula XVIII



$$CH_2=\underset{CH_3}{C}-\overset{O}{C}OCH_2CH_2\left[-O\overset{O}{C}\underset{H}{N}-R^{16}-\underset{H}{N}\overset{O}{C}OCH_2CH_2OCH_2CH_2O\overset{O}{C}\underset{H}{N}-R^{16}-\underset{H}{N}\overset{O}{C}O(CH_2)_m-\left(\overset{CH_3}{\underset{CH_3}{Si}}O\right)_p\overset{CH_3}{\underset{CH_3}{Si}}-(CH_2)_m-\right]_a O\overset{O}{C}\underset{H}{N}-R_{16}-\underset{H}{N}\overset{O}{C}OCH_2CH_2OCH_2CH_2O\overset{O}{C}\underset{H}{N}-R^{16}-\underset{H}{N}\overset{O}{C}O-CH_2CH_2COO\overset{CH_3}{C}=CH_2$$

wherein R^{16} is a diradical of a diisocyanate after removal of the isocyanate group, such as the diradical of isophorone diisocyanate. Another suitable silicone containing macromer is compound of formula X (in which x + y is a number in the range of 10 to 30) formed by the reaction of fluoroether, hydroxy-terminated polydimethylsiloxane, isophorone diisocyanate and isocyanatoethylmethacrylate.

Formula XIX



[0078] Other silicone-containing components suitable for use in this disclosure include those described is WO 96/31792 such as macromers containing polysiloxane, polyalkylene ether, diisocyanate, polyfluorinated hydrocarbon, polyfluorinated ether and polysaccharide groups. Another class of suitable silicone-containing components includes silicone containing macromers made via GTP, such as those disclosed in U.S. Pat Nos. 5,314,960, 5,331,067, 5,244,981, 5,371,147 and 6,367,929. U.S. Pat. Nos. 5,321,108; 5,387,662 and 5,539,016 describe polysiloxanes with a polar fluorinated graft or side group having a hydrogen atom attached to a terminal difluoro-substituted carbon atom. US 2002/0016383 describe hydrophilic siloxanyl methacrylates containing ether and siloxanyl linkanges and crosslinkable monomers containing polyether and polysiloxanyl groups. Any of the foregoing polysiloxanes can also be used as the silicone-containing component in this disclosure.

[0079] In one embodiment of the present invention where a modulus of less than about 120 psi is desired, the majority of the mass fraction of the silicone-containing components used in the lens formulation should contain only one polymerizable functional group ("monofunctional silicone containing component"). In this embodiment, to insure the desired balance of oxygen transmissibility and modulus it is preferred that all components having more than one polymerizable functional group ("multifunctional components") make up no more than 10 mmol/100 g of the reactive components, and preferably no more than 7 mmol/100 g of the reactive components.

[0080] In another embodiment, the reaction mixtures are substantially free of silicone containing components which contain trimethylsiloxy groups.

[0081] The silicone containing components may be present in amounts up to about 85 weight %, and in some embodiments between about 10 and about 80 and in other embodiments between about 20 and about 70 weight %, based upon all reactive components.

[0082] Other components that can be present in the reaction mixture used to form the contact lenses of this invention include wetting agents, such as those disclosed in US 6,367,929, WO03/22321, WO03/22322, compatibilizing components, such as those disclosed in US2003/162862 and US2003/125498, ultra-violet absorbing compounds, medicinal agents, antimicrobial compounds, copolymerizable and nonpolymerizable dyes, including photochromic dyes, release agents, reactive tints, pigments, pharmaceutical and nutriceutical compounds, combinations thereof and the like. The sum of additional components may be up to about 20 wt%. In one embodiment the reaction mixtures comprise up to about 18 wt% wetting agent, and in another embodiment, between about 5 and about 18 wt% wetting agent.

[0083] A polymerization catalyst may be included in the reaction mixture. The polymerization initiators includes compounds such as lauroyl peroxide, benzoyl peroxide, isopropyl percarbonate, azobisisobutyronitrile, and the like, that generate free radicals at moderately elevated temperatures, and photoinitiator systems such as aromatic alpha-hydroxy ketones, alkoxyoxybenzoins, acetophenones, acylphosphine oxides, bisacylphosphine oxides, and a tertiary amine plus a diketone, mixtures thereof and the like. Illustrative examples of photo initiators are 1-hydroxycyclohexyl phenyl ketone, 2-hydroxy-2-methyl-1-phenyl-propan-1-one, bis(2,6-dimethoxybenzoyl)-2,4-4-trimethylpentyl phosphine oxide (DMBAPO), bis(2,4,6-trimethylbenzoyl)-phenyl phosphineoxide (Irgacure 819), 2,4,6-trimethylbenzyldiphenyl phosphine oxide and 2,4,6-trimethylbenzoyl diphenylphosphine oxide, benzoin methyl ester and a combination of camphorquinone and ethyl 4-(N,N-dimethylamino)benzoate. Commercially available visible light initiator systems include Irgacure 819, Irgacure 1700, Irgacure 1800, Irgacure 819, Irgacure 1850 (all from Ciba Specialty Chemicals) and Lucirin TPO initiator (available from BASF). Commercially available UV photoinitiators include Darocur 1173 and Darocur 2959 (Ciba Specialty Chemicals). These and other photoinitators which may be used are disclosed in Volume III, Photoinitiators for Free Radical Cationic & Anionic Photopolymerization, 2nd Edition by J.V. Crivello& K. Dietliker; edited by G. Bradley; John Wiley and Sons; New York; 1998. The initiator is used in the reaction mixture in effective amounts to initiate photopolymerization of the reaction mixture, e.g., from about 0.1 to about 2 parts by weight per 100 parts of reactive monomer.

Polymerization of the reaction mixture can be initiated using the appropriate choice of heat or visible or ultraviolet light or other means depending on the polymerization initiator used. Alternatively, initiation can be conducted without a photoinitiator using, for example, e-beam. However, when a photoinitiator is used, the preferred initiators are bisacylphosphine oxides, such as bis(2,4,6-trimethylbenzoyl)-phenyl phosphine oxide (Irgacure 819®) or a combination of 1-hydroxycyclohexyl phenyl ketone and bis(2,6-dimethoxybenzoyl)-2,4-4-trimethylpentyl phosphine oxide (DMBAPO), and in another embodiment the method of polymerization initiation is via visible light activation. A preferred initiator is bis(2,4,6-trimethylbenzoyl)-phenyl phosphine oxide (Irgacure 819®).

[0084] The reactive components (silicone containing component, hydrophilic monomers, wetting agents, and other components which are reacted to form the lens) are mixed together either with or without a diluent to form the reaction mixture.

[0085] In one embodiment a diluent is used having a polarity sufficiently low to solubilize the non-polar components in the reactive mixture at reaction conditions. One way to characterize the polarity of the diluents of the present disclosure is via the Hansen solubility parameter, δp. In certain embodiments, the δp is less than about 10, and preferably less than about 6. Suitable diluents are further disclosed in US Ser. No 60/452898 and US 6,020,445.

[0086] Classes of suitable diluents include, without limitation, alcohols having 2 to 20 carbons, amides having 10 to 20 carbon atoms derived from primary amines, ethers, polyethers, ketones having 3 to 10 carbon atoms, and carboxylic acids having 8 to 20 carbon atoms. For all solvents, as the number of carbons increase, the number of polar moieties may also be increased to provide the desired level of water miscibility. In some embodiments, primary and tertiary alcohols are preferred. Preferred classes include alcohols having 4 to 20 carbons and carboxylic acids having 10 to 20 carbon atoms.

[0087] In one embodiment the diluents are selected from 1,2-octanediol, t-amyl alcohol, 3-methyl-3-pentanol, decanoic acid, 3,7-dimethyl-3-octanol, tripropylene glycol methyl ether (TPME), butoxy ethyl acetate, mixtures thereof and the like.

[0088] In one embodiment the diluents are selected from diluents that have some degree of solubility in water. In some embodiments at least about three percent of the diluent is miscible water. Examples of water soluble diluents include 1-octanol, 1-pentanol, 1-hexanol, 2-hexanol, 2-octanol, 3-methyl-3-pentanol, 2-pentanol, t-amyl alcohol, *tert*-butanol, 2-butanol, 1-butanol, 2-methyl-2-pentanol, 2-ethyl-1-butanol, ethanol, 3,3-dimethyl-2-butanol, decanoic acid, octanoic acid, dodecanoic acid, 1-ethoxy-2- propanol, 1-tert-butoxy-2-propanol, EH-5 (commercially available from Ethox Chemicals), 2,3,6,7-tetrahydroxy-2,3,6,7-tetramethyl octane, 9-(1-methylethyl)-2,5,8,10,13,16-hexaoxaheptadecane, 3,5,7,9,11,13-hexamethoxy-1-tetradecanol, mixtures thereof and the like.

[0089] The reactive mixture of the present disclosure may be cured via any known process for molding the reaction mixture in the production of contact lenses, including spincasting and static casting. Spincasting methods are disclosed in U.S. Patents Nos. 3,408,429 and 3,660,545, and static casting methods are disclosed in U.S. Patents Nos. 4,113,224 and 4,197,266. In one embodiment, the contact lenses of this invention are formed by the direct molding of the silicone hydrogels, which is economical, and enables precise control over the final shape of the hydrated lens. For this method, the reaction mixture is placed in a mold having the shape of the final desired silicone hydrogel, i.e. water-swollen polymer, and the reaction mixture is subjected to conditions whereby the monomers polymerize, to thereby produce a polymer in the approximate shape of the final desired product.

[0090] After curing the lens is subjected to extraction to remove unreacted components and release the lens from the lens mold. The extraction may be done using conventional extraction fluids, such as organic solvents, such as alcohols or may be extracted using aqueous solutions.

[0091] Aqueous solutions are solutions which comprise water. In one case the aqueous solutions of the present disclosure comprise at least about 30 % water, in some cases at least about 50% water, in some cases at least about 70% water and in others at least about 90 weight% water. Aqueous solutions may also include additional water soluble components such as the uncrosslinked statistical copolymers of the present invention, release agents, wetting agents, slip agents, pharmaceutical and nutraceutical components, combinations thereof and the like. Release agents are compounds or mixtures of compounds which, when combined with water, decrease the time required to release a contact lens from a mold, as compared to the time required to release such a lens using an aqueous solution that does not comprise the release agent. In one case the aqueous solutions comprise less than about 10 weight %, and in others less than about 5 weight % organic solvents such as isopropyl alcohol, and in another case are free from organic solvents. In these cases the aqueous solutions do not require special handling, such as purification, recycling or special disposal procedures.

[0092] In various cases, extraction can be accomplished, for example, via immersion of the lens in an aqueous solution or exposing the lens to a flow of an aqueous solution. In various cases, extraction can also include, for example, one or more of: heating the aqueous solution; stirring the aqueous solution; increasing the level of release aid in the aqueous solution to a level sufficient to cause release of the lens; mechanical or ultrasonic agitation of the lens; and incorporating at least one leach aid in the aqueous solution to a level sufficient to facilitate adequate removal of unreacted components from the lens. The foregoing may be conducted in batch or continuous processes, with or without the addition of heat, agitation or both.

[0093] Some cases can also include the application of physical agitation to facilitate leach and release. For example, the lens mold part to which a lens is adhered, can be vibrated or caused to move back and forth within an aqueous solution. Other cases may include ultrasonic waves through the aqueous solution.

[0094] These and other similar processes can provide an acceptable means of releasing the lens.

[0095] As used herein, "released from a mold" means that a lens is either completely separated from the mold, or is only loosely attached so that it can be removed with mild agitation or pushed off with a swab. In the process of the present disclosure the conditions used include temperature less than 99°C for less than about 1 hour.

[0096] The lenses may be sterilized by known means such as, but not limited to autoclaving. The uncrosslinked, statistical copolymers may be added before or after polymerization.

[0097] In one embodiment, contact lenses formed from the polymers of the present invention display excellent compatibility with the components of human tears.

[0098] Human tears are complex and contain a mixture of proteins, lipids and other components which help to keep the eye lubricated. Examples of proteins which are found in human tears include lactoferrin, lysozyme, lipocalin, serum albumin, and secretory immunoglobulin A.

[0099] Lysozyme is generally present in human tears in substantial concentrations. Lysozyme is bacteriolytic and believed to protect the eye against bacterial infection. The amount of lysozyme which associates with commercially available contact lenses when worn, varies greatly from only a few micrograms to over 800 micrograms for etafilcon A contact lenses (commercially available from Johnson & Johnson Vision Care, Inc., under the ACUVUE and ACUVUE2 brand names). Etafilcon A contact lenses have been commercially available for many years and display some of the lowest adverse event rates of any soft contact lens. Thus, contact lenses which uptake substantial levels of lysozyme are desirable. The lenses of the present invention uptake at least about 50 μg, 100 μg, 200 μg, 500 μg of lysozyme and in some embodiments at least about 800μg lysozyme, all from a 2 mg/ml solution over 72 hours incubation at 35°C. In another case the silicone hydrogels of the present disclosure display both desirable lysozyme uptake and water content. Desirable water contents are those between about 20 and about 70%, between about 25 and about 70%, and in some cases between about 25 and about 65 wt%. The foregoing ranges may be combined in any variation.

[0100] In addition to lysozyme, lactoferrin is another important cationic protein in the tears, mainly by the virtue of its anti-bacterial and anti-inflammatory properties. Upon wear, contact lenses uptake various amounts of lactoferrin, depending upon their polymer composition (for non-surface modified lenses) and the composition and integrity of the surface coating (for surface modified contact lenses). In one embodiment of the present invention, lenses uptake at least about 5 μg, and in some embodiments, at least about 10 micrograms lactoferrin following overnight soaking of the lenses in 2 mls of a 2 mg/ml lactoferrin solution. The lactoferrin solution contains lactoferrin from human milk (Sigma L-0520) solubilized at a concentration of 2 mg/ml in phosphate saline buffer. Lenses are incubated in 2 ml of the lactoferrin solution per lens for 72 hours at 35°C, using the procedure described below for lysozyme. Lactoferrin and lysozyme also act synergistically as bactericidal agents.

[0101] The form of the proteins in, on and associated with the lens is also important. Denatured proteins are believed to contribute to corneal inflammatory events and wearer discomfort. Environmental factors such as pH, ocular surface temperature, wear time and closed eye wear are believed to contribute to the denaturation of proteins. However, lenses of different compositions can display markedly different protein uptake and denaturation profiles. In one embodiment of the present invention, a majority of the proteins uptaken by the lenses of the present invention are and remain in the native form during wear. In other embodiments at least about 50%, at least about 70 and at least about 80% of uptaken proteins are and remain native after 24 hours, 3 days and during the intended wear period.

[0102] The contact lenses of the present invention also uptake less than about 10%, and in other embodiments less than about 5% Polyquaternium-1 ("PQ1") from an ophthalmic solution containing 0.001 wt% PQ1 and citrate dihydrate and citric acid monohydrate.

[0103] The lenses of the present invention have a number of desirable properties in addition to the protein uptake characteristics described herein. In one embodiment the lenses have an oxygen permeability greater than about 50 and in other embodiments greater than about 60, in other embodiments greater than about 80 and in still other embodiments at least about 100. In some embodiments the lenses have tensile moduli less than about 100 psi.

[0104] The contact lenses of the present invention have a balance of properties which makes them particularly useful. Such properties include clarity, water content, oxygen permeability and contact angle. Silicone hydrogel contact lenses formed from the polymers of the present invention display contact angles of less than about 70°, less than about 50° and in some embodiments less than about 30° all as measured by sessile drop, and decreases in contact angle of about 30% and in some embodiments about 50% or more.

[0105] In one embodiment, the biomedical devices are contact lenses having a water content of greater than about 20% and more preferably greater than about 25%.

[0106] As used herein clarity means substantially free from visible haze. Preferably clear lenses have a haze value of less than about 150%, more preferably less than about 100%.

[0107] Suitable oxygen permeabilities for silicone containing lenses are preferably greater than about 40 barrer and more preferably greater than about 60 barrer.

[0108] In some embodiments the contact lenses of the present invention have combinations of the above described oxygen permeability, water content and contact angle. All combinations of the above ranges are deemed to be within the present invention.

[0109] It will be appreciated that all of the tests specified herein have a certain amount of inherent test error. Accordingly, results reported herein are not to be taken as absolute numbers, but numerical ranges based upon the precision of the particular test.

[0110] Wettability of lenses was determined using a sessile drop technique measured using KRUSS DSA-100 TM instrument at room temperature and using DI water as probe solution. The lenses to be tested (3-5/sample) were rinsed in DI water to remove carry over from packing solution. Each test lens was placed on blotting lint free wipes which were dampened with packing solution. Both sides of the lens were contacted with the wipe to remove surface water without drying the lens. To ensure proper flattening, lenses were placed "bowl side down" on the convex surface on contact lens plastic moulds. The plastic mould and the lens were placed in the sessile drop instrument holder, ensuring proper central syringe alignment and that the syringe corresponds to the assigned liquid. A 3 to 4 microliter of DI water drop was formed on the syringe tip using DSA 100-Drop Shape Analysis software ensuring the liquid drop was hanging away from the lens. The drop was released smoothly on the lens surface by moving the needle down. The needle was withdrawn away immediately after dispensing the drop. The liquid drop was allowed to equilibrate on the lens for 5 to 10 seconds and the contact angle was measured between the drop image and the lens surface.

[0111] The water content may be measured as follows: lenses to be tested were allowed to sit in packing solution for 24 hours. Each of three test lens were removed from packing solution using a sponge tipped swab and placed on blotting wipes which have been dampened with packing solution. Both sides of the lens were contacted with the wipe. Using tweezers, the test lens were placed in a weighing pan and weighed. The two more sets of samples were prepared and weighed as above. The pan was weighed three times and the average is the wet weight.

[0112] The dry weight was measured by placing the sample pans in a vacuum oven which has been preheated to 60°C for 30 minutes. Vacuum was applied until at least 0.4 inches Hg is attained. The vacuum valve and pump were turned off and the lenses were dried for four hours. The purge valve was opened and the oven was allowed reach atmospheric pressure. The pans were removed and weighed. The water content was calculated as follows:

$$\text{Wet weight} = \text{combined wet weight of pan and lenses} - \text{weight of weighing pan}$$

$$\text{Dry weight} = \text{combined dry weight of pan and lens} - \text{weight of weighing pan}$$

$$\%\ \text{water content} = \frac{\underline{(\text{wet weight} - \text{dry weight})}}{\text{wet weight}} \times 100$$

[0113] The average and standard deviation of the water content are calculated for the samples are reported.

[0114] Haze may measured by placing a hydrated test lens in borate buffered saline in a clear 20 x 40 x 10 mm glass cell at ambient temperature above a flat black background, illuminating from below with a fiber optic lamp (Titan Tool Supply Co. fiber optic light with 0.5" diameter light guide set at a power setting of 4-5.4) at an angle 66° normal to the lens cell, and capturing an image of the lens from above, normal to the lens cell with a video camera (DVC 1300C:19130 RGB camera with Navitar TV Zoom 7000 zoom lens) placed 14 mm above the lens platform. The background scatter is subtracted from the scatter of the lens by subtracting an image of a blank cell using EPIX XCAP V 1.0 software. The subtracted scattered light image is quantitatively analyzed, by integrating over the central 10 mm of the lens, and then comparing to a -1.00 diopter CSI Thin Lens®, which is arbitrarily set at a haze value of 100, with no lens set as a haze value of 0. Five lenses are analyzed and the results are averaged to generate a haze value as a percentage of the standard CSI lens.

[0115] Oxygen permeability (Dk) may be determined by the polarographic method generally described in ISO 9913-1: 1996(E), but with the following variations. The measurement is conducted at an environment containing 2.1% oxygen. This environment is created by equipping the test chamber with nitrogen and air inputs set at the appropriate ratio, for example 1800 ml/min of nitrogen and 200 ml/min of air. The t/Dk is calculated using the adjusted p_{O2}. Borate buffered saline was used. The dark current was measured by using a pure humidified nitrogen environment instead of applying MMA lenses. The lenses were not blotted before measuring. Four lenses were stacked instead of using lenses of varied thickness. A curved sensor was used in place of a flat sensor. The resulting Dk value is reported in barrers.

[0116] Lysozyme uptake was measured as follows: The lysozyme solution used for the lysozyme uptake testing contained lysozyme from chicken egg white (Sigma, L7651) solubilized at a concentration of 2 mg/ml in phosphate saline buffer supplemented by Sodium bicarbonate at 1.37g/l and D-Glucose at 0.1 g/l.

[0117] Three lenses for each example were tested using each protein solution, and three were tested using PBS as a control solution. The test lenses were blotted on sterile gauze to remove packing solution and aseptically transferred, using sterile forceps, into sterile, 24 well cell culture plates (one lens per well) each well containing 2 ml of lysozyme solution. Each lens was fully immersed in the solution. 2 ml of the lysozyme solution was placed in a well without a contact lens as a control.

[0118] The plates containing the lenses and the control plates containing only protein solution and the lenses in the PBS, were sealed using parafilm to prevent evaporation and dehydration, placed onto an orbital shaker and incubated at 35°C, with agitation at 100 rpm for 72 hours. After the 72 hour incubation period the lenses were rinsed 3 to 5 times by dipping lenses into three (3) separate vials containing approximately 200 ml volume of PBS. The lenses were blotted on a paper towel to remove excess PBS solution and transferred into sterile conical tubes (1 lens per tube), each tube containing a volume of PBS determined based upon an estimate of lysozyme uptake expected based upon on each lens composition. The lysozyme concentration in each tube to be tested needs to be within the albumin standards range as described by the manufacturer (0.05 micogram to 30 micrograms). Samples known to uptake a level of lysozyme lower than 100 μg per lens were diluted 5 times. Samples known to uptake levels of lysozyme higher than 500 μg per lens (such as etafilcon A lenses) are diluted 20 times.

[0119] 1 ml aliquot of PBS was used for all samples other than etafilcon. 20ml were used for etafilcon A lens. Each control lens was identically processed, except that the well plates contained PBS instead of lysozyme solution.

[0120] Lysozyme uptake was determined using on-lens bicinchoninic acid method using QP-BCA kit (Sigma, QP-BCA) following the procedure described by the manufacturer (the standards prep is described in the kit) and is calculated by subtracting the optical density measured on PBS soaked lenses (background) from the optical density determined on lenses soaked in lysozyme solution.

[0121] Optical density was measured using a SynergyII Micro-plate reader capable for reading optical density at 562nm.

PQ-1 Uptake

[0122] PQ1 uptake was measured as follows: The HPLC is calibrated using a series of standard PQ1 solutions prepared having the following concentrations: 2, 4, 6, 8, 12 and 15 μg/mL. Lenses were placed into polypropylene contact lens case with 3 mL of Optifree Replenish (which contains 0.001 wt% PQ1, 0.56% citrate dihydrate and 0.021 % citric acid monohydrate (wt/wt)) and is commercially available from Alcon). A control lens case, containing 3 mL of solution, but no contact lens was also prepared. The lenses and control solutions were allowed to sit at room temperature for 72 hours. 1 ml of solution was removed from each of the samples and controls and mixed with trifluoroacetic acid (10 μL). The analysis was conducted using HPLC/ELSD and a Phenomenex Luna C4 (4.6 mm x 5 mm; 5 μm particle size) column and the following conditions:

Instrument: Agilent 1200 HPLC or equivalent with Sedere Sedex 85 ELSD

Sedex 85 ELSD: T = 60°C, Gain = 10, Pressure = 3.4 bar, Filter = 1s
Mobile Phase A: H_20 (0.1% TFA)
Mobile Phase B: Acetonitrile (0.1% TFA)
Column Temperature: 40 °C
Injection Volume: 100 μL

Table I. HPLC Conditions.

Time (minutes)	%A	%B	Flow Rate (mL/min)
0.00	100	0	1.2
1.00	100	0	1.2
5.00	0	100	1.2
8.50	0	100	1.2
8.60	100	0	1.2
12.00	100	0	1.2

Three lenses were run for each analysis, and the results were averaged.
The non-limiting examples below further describe this invention.

ACA1	3-acrylamidopropanoic acid
ACA2	5-acrylamidopentanoic acid
AMPS	2-Acrylamido-2-methylpropane sulfonic acid, CAS 15214-89-8
Bis HEAA	N,N bis-(2-hydroxyethyl)acrylamide
Blue Hema	the reaction product of Reactive Blue 4 and HEMA, as described in Example 4 of U.S. Pat. no. 5,944,853
DMA	N,N dimethyl acrylamide (Jarchem)
D3O	3,7-dimethyl-3-octanol
Norbloc	2-(2'-hydroxy-5-methacrylyloxyethylphenyl)-2H-benzotriazole
Irgacure 819	bis(2,4,6-trimethylbenzoyl)-phenylphosphineoxide
MAA	methacrylic acid
MBA	N,N'-Methylene-bisacrylamide (Sigma-Aldrich)
PVP	polyvinyl pyrrolidone (K90)
HO-mPDMS	mono-(2-hydroxy-3-methacryloxypropyl)-propyl ether terminated, n-butyl terminated polydimethylsiloxane (400-1000 MW))
SA2	N-(2,3-dihydroxypropane)-N'-(propyl tetra(dimethylsiloxy) dimethylbutylsilane)acrylamide , made by working example 2 and shown in Formula 8 of US2011/0237766
PQ1	poly[(dimethyliminio)-2-butene-1,4-diyl chloride (1:1)], α-[4-[tris(2-hydroxyethyl)ammonio]-2-buten-1-yl]-ω-[tris(2-hydroxyethyl)ammonio]-, chloride (CAS 75345-27-6)

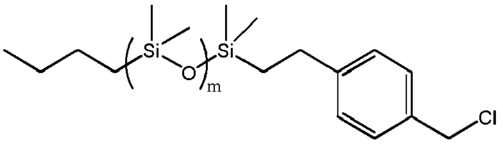
Synthesis 1

S-hexyl- S-4-(2-(n-butylpolydimethylsiloxysilyl)ethyl)benzyl carbonotrithioate

[0123] XG-1996 (shown in Formula I, MW distribution centered around about 1000 g/mole, which corresponds to an average repeat, m of 10-12), (10 g, 10 moles),

Formula I

XG-1996: Chloromethylphenylethylpolydimethylsiloxane MW ~ 1000 g/mole



was dissolved in approx. 250 mL of acetone in a 1 L round bottom flask. Sodium hexyltrithiocarbonate (NaHTTC) was dissolved in 100 mL acetone and added to the reaction mixture. The reaction mixture was stirred overnight. A white solid precipitated out of the bright yellow solution. Acetone was removed via rotary-evaporation, and the crude product was partitioned between 250 mL DI water and 250 mL hexane. The hexane layer was separated out and the aqueous layer was extracted with hexane (3 x 200mL). All organic layers were combined, washed with brine (250mL) and dried over Na_2SO_4. The crude product in hexane was passed over a silica gel plug to remove cloudiness. Hexane was removed via rotary-evaporation leaving the product (XG-1996-HTTC) in the form of a clear yellow oil. Structure was confirmed using NMR spectroscopy.

Synthesis 2: 3-acrylamidopropanoic acid

[0124] A fresh solution of sodium methoxide was prepared by dissolving 4.6g of metallic sodium in 250mL of stirred methanol, to which, Beta-alanine (3-aminopentanoic acid, 8.9g, 0.1mole) was added.

[0125] Acryloyl chloride (10.0g, 1.1eq.) was added dropwise to a stirred suspension of the given mixture, while maintaining the temperature below 35C at all times. The mixture was stirred for an additional 30 minutes, concentrated to about 50mL and filtered to remove the sodium chloride formed. The hygroscopic product was treated with pH 3 aqueous HCl, followed by evaporation of the volatiles ad filtration through silica gel using 3-5% (v/v) methanol in ethyl acetate.

Synthesis 3: 5-Acrylamidopentanoic acid (ACA II)

[0126] A fresh solution of sodium methoxide was prepared by dissolving 5.76g of metallic sodium in 250mL of stirred methanol. Valeric acid (5-aminopentanoic acid, 14.68g, 0.125mole) was dissolved in the given solution and 2.1g of sodium carbonate was added to the mixture.

Acryloyl chloride (12.31g, 1.1eq.) was added dropwise to a stirred suspension of the given mixture, while maintaining the temperature below 35C at all times. The mixture was stirred for an additional 30 minutes and filtered to remove the sodium chloride and residual carbonate present.

[0127] Evaporation of the methanol and other volatiles at reduced pressure, followed by washing the residue with 2x75mL of acetonitrile yielded 20.4g of the sodium salt of 5-acrylamidopentanoic acid. The free carboxylic acid was obtained pure after acidification of the salt in pH 3 aqueous HCl, evaporation of the residual water, followed by filtration through silica gel using 2-3% (v/v) methanol in ethyl acetate.

Preparation 1

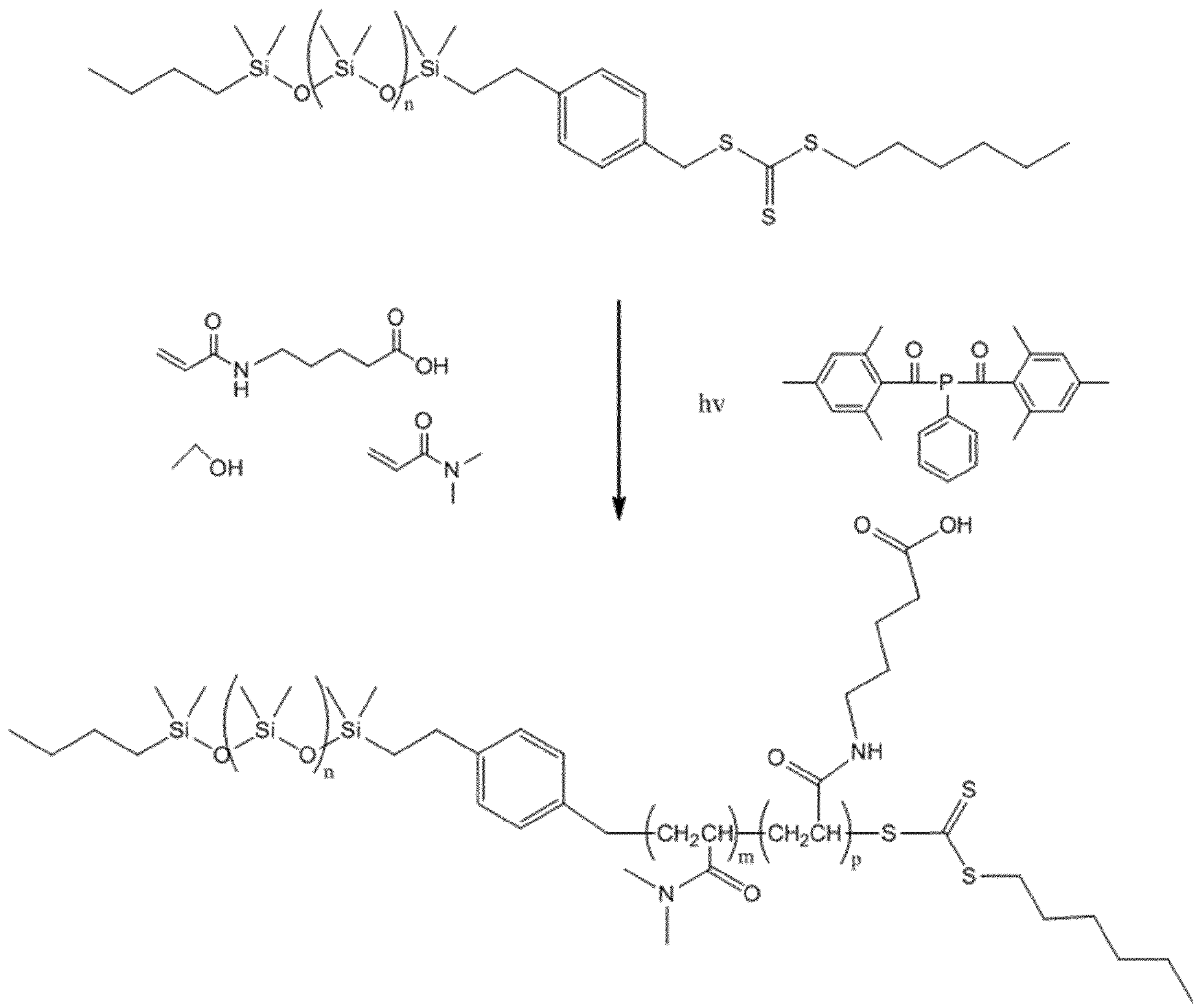
[0128] N,N-dimethylacrylamide (DMA) and further purified *via* vacuum distillation. 5-acrylamidopentanoic acid (ACA2) was prepared according to Synthesis 3 The siloxy-functional benzyltrithiocarbonate, S-XG-1996-S'-hexyl-trithiocarbonate, was prepared according to Synthesis 1, above. Irgacure 819 was dissolved in D3O (10mg/mL).

[0129] The polymerization solution was prepared by dissolving 1.1g ACA2 in 3mL of ethanol and 1.5g DMA in an amber 20mL glass vial. Next, 166mg S-XG-1996-S'-hexyltrithiocarbonate, and 1.51mg (151ul of stock solution) Irgacure-819 were added to the monomer and warmed/stirred to ensure homogeneity (CTA to initiator ratio = 20). The amber vial containing the final polymerization solution was sealed with a rubber septum and purged for 20 minutes with N_2 to remove O_2 from the solution. Finally the sealed jar was placed in an N_2 glove-box for storage.

[0130] The polymerization solution was cured under an N_2 atmosphere with 4 standard Phillips TL 20W/03 RS bulbs at intensity of 2.0 mW/cm^2 for 45 minutes. Prior to curing, the polymerization solution was poured into an 80mm diameter crystallization dish, which was then placed on a reflective glass surface.

[0131] After curing, the resulting highly viscous polymerized material was dissolved in 5mL of ethanol. The solution was stirred then added drop-wise to vigorously stirring diethyl ether to precipitate product. A 500mL flask filled with 200mL of ether was used. The precipitated polymer was dried *in vacuo* for several hours. The polymer was analyzed for MW and MWD via SEC-MALLS. The degree of polymerization of the hydrophilic segment was about 300.

[0132] The reaction is shown below.



Preparation 2

[0133] N,N-dimethylacrylamide (DMA) was purified *via* vacuum distillation. 5-acrylamidopentanoic acid (ACA2) was prepared according to Synthesis 3. The siloxy-functional benzyltrithiocarbonate, S-XG-1996-S'-hexyl-trithiocarbonate, was prepared according to Synthesis 1. Irgacure 819, was obtained from Ciba Specialty Chemicals and dissolved in D3O (10mg/mL).

[0134] The polymerization solution was prepared by dissolving 2.07g ACA2 in 6mL ethanol and 300mg DMA in an amber 20mL glass vial. Next, 58mg S-XG-1996-S'-hexyl-trithiocarbonate, and 1.06mg (106ul of stock solution) Irgacure-819 were added to the monomer and warmed/stirred to ensure homogeneity (CTA to initiator ratio = 20). The amber vial containing the final polymerization solution was sealed with a rubber septum and purged for 20 minutes with N_2 to remove O_2 from the solution. Finally the sealed vial was placed in an N_2 glove-box for storage. The polymerization solution was cured and purified as described in Preparation 1. The polymer was analyzed for MW and MWD via SEC-MALLS. The degree of polymerization of the hydrophilic segment was about 300.

Preparations 3 and 4 (PDMA/ACA2 copolymer, dp=300)

[0135] N,N-dimethylacrylamide (DMA) was obtained from Jarchem and further purified *via* vacuum distillation. S-benzyl-S'-hexyl-trithiocarbonate was prepared according to Synthesis 1. Irgacure 819 (1.06 mg) was dissolved in D3O (10mg/mL).

]

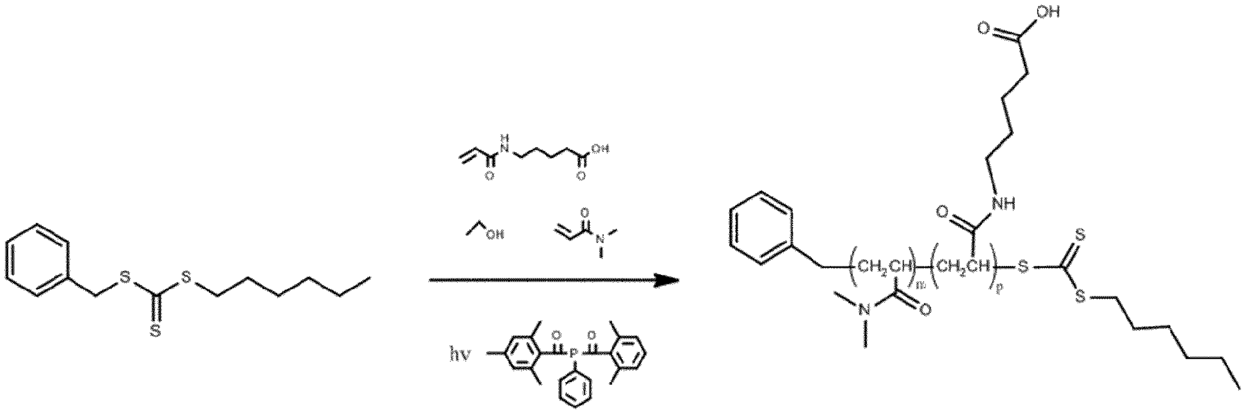
Table 2

Materials	Prep 3	Prep 4
	80DMA/20ACA2	70DMA/30ACA2
CTA	14 mg	20mg
Ethanol	6 Ml	3mL
DMA	300 mg	1.5g
ACA II	2.07g	1.1g
Irgacure-819	1.06mg	1.51mg

[0136] The polymerization solution was prepared by dissolving the ACA2 in ethanol and DMA in an amber 20mL glass vial. Next, S-benzyl-S'-hexyl-trithiocarbonate, and (1.51ul of stock solution) Irgacure-819 were added to the monomer and warmed/stirred to ensure homogeneity (CTA to initiator ratio = 20). The amounts for each component are shown in Table 2, above. The amber vial containing the final polymerization solution was sealed with a rubber septum and purged for 20 minutes with N_2 to remove O_2 from the solution. Finally the sealed jar was placed in an N_2 glove-box for storage.

[0137] The polymerization solution was cured under an N_2 atmosphere with 4 standard Phillips TL 20W/03 RS bulbs at intensity of 2.0 mW/cm^2 for 45 minutes. Prior to curing, the polymerization solution was poured into an 80mm diameter crystallization dish, which was then placed on a reflective glass surface.

[0138] The resulting polymerized material was dissolved in 5mL of ethanol. The solution was stirred then added dropwise to vigorously stirring diethyl ether to precipitate product. A 500mL flask filled with 200mL of ether was used. The precipitated polymer was dried *in vacuo* for several hours. The polymer was analyzed for MW and MWD via SEC-MALLS. The reaction is shown below.



Examples 1-12

[0139] Three senofilcon lenses were removed from their packages and transferred glass vials containing packing solution containing the non-reactive polysiloxane terminated hydrophilic polymer ("NRPTHP") produced in Preparation 1 through 4 in the concentrations shown in Table 1. The lenses were re-packaged in the NRPTHP packing solution, autoclaved at 121 °C for 28 minutes and, after sterilization, were allowed to soak in the NRPTHP packing solution at ambient temperature for at least 24 hours. The contact angle, lysozyme uptake and PQ-1 uptake of the lenses were measured and are reported in Table 3. Untreated senofilcon lenses were also tested as a control.

Table 3

Ex#	Prep	DMA:ionic	[NRPTHP] (ppm)	CA°	%PQ1 uptake	Lysozyme (μg/ lens)
1*	1	70:30ACA2	50	24±5	7±1	19±3
2*	1	70:30ACA2	500	28±6	0±0	44±7
3	1	70:30ACA2	1000	29±7	0±5	51±6
4*	2	80:20ACA2	50	24±13	9±0	33±5

(continued)

Ex#	Prep	DMA:ionic	[NRPTHP] (ppm)	CA°	% PQ1 uptake	Lysozyme (μg/ lens)
5*	2	80:20ACA2	500	32±18	24±9	58±7
6*	2	80:20ACA2	1000	33±16	46±7	65±4
7*	3	80:20ACA2	50	17±4	7±5	23±4
8*	3	80:20ACA2	500	22±12	13±1	43±5
9*	3	80:20ACA2	1000	21±6	5±6	42±2
10*	4	70:30ACA2	50	30±15	1±0	23±2
11*	4	70:30ACA2	500	21±19	24±13	65±3
12*	4	70:30ACA2	1000	37±20	25±13	66±5
CE1	5	70:30AA	500	NM	19+5	31+7
CE2	6	20:80AA	500	NM	65+21	65+5
CE3	7	70:30AA	500	NM	10+2	26+3
CE4	8	20:80AA	500	NM	45±9	73+4
*reference example						

[0140] The data in Table 3 shows that non-reactive hydrophilic copolymers comprising a randomly copolymerized anionic monomer are effective at reducing contact angle. The hydrophilic copolymer of Preparations 1 and 2 contained an anionic component, APA which in the concentrations of Examples 2 through 4 were effective in increasing lysozyme uptake to at least about 50 μg/lens and decreasing PQ1 uptake. Lysozyme is a protein native to the eye which, when uptaken in a contact lens in the native form, is believed to improve the biocompatibility of the contact lens. PQ1 is a preservative commonly used in contact lens multipurpose solutions. Uptake of PQ1 to a contact lens in amounts greater than about 10% can cause staining and is therefore undesirable. Examples 1-12 display lower values of PQ1 uptake compared to the lenses treated with acrylic acid containing polymers of Comparative Examples 1-4. The lenses of Examples 2-4 and 9 display a desirable balance of contact angle, lysozyme and PQ1 uptake.

Preparation Examples 5 and 6

[0141] DMA was purified *via* vacuum distillation. Acrylic acid (Sigma Aldrich) was used as received. S-XG-1996-S'-hexyl-trithiocarbonate, was prepared according to Synthesis 1. Irgacure 819, was dissolved in decanol (10mg/mL).

Table 3a

Materials	[CE5-30%] (gm)	[CE6-80%] (gm)
CTA	0.553	0.508
Pentanol	13.0	11.0
DMA	10.0	3.00
Acrylic Acid	3.12	8.73
Irgacure-819	0.00201	0.00211

[0142] The polymerization solution was prepared by adding distilled DMA and acrylic acid to an amber 30mL glass jar. Next, pentanol, S-XG-1996-S'-hexyl-trithiocarbonate, and Irgacure-819 stock solution were added to the monomer in the amounts in Table 3a and warmed/stirred to ensure homogeneity (CTA to initiator ratio = 100). The amber jar containing the final polymerization solution was sealed with a rubber septum and purged for 20 minutes with N_2 to remove O_2 from the solution. Finally the sealed jar was placed in an N_2 glove-box for overnight storage.

[0143] The polymerization solution was cured under an N_2 atmosphere with 4 standard Phillips TL 20W/03 RS bulbs at intensity of 2.0 mW/cm^2 for 1 hour. Prior to curing, the polymerization solution was poured into a 125mm diameter crystallization dish, which was then placed on a reflective glass surface.

[0144] After curing for 1 hour, the resulting highly viscous polymerized material was dissolved in 30mL of ethanol. The solution was stirred overnight then transferred to an addition funnel using 20mL of ethanol to rinse out the crystallization dish. The polymer solution was added drop-wise to vigorously stirring diethyl ether to precipitate product. A 1L flask filled with 500mL of ether was used. The precipitated polymer was dried *in vacuo* for several hours and then subjected to further purification via Soxhlet Extraction with diethyl ether. The polymer was analyzed for MW and MWD via SEC-MALLS.

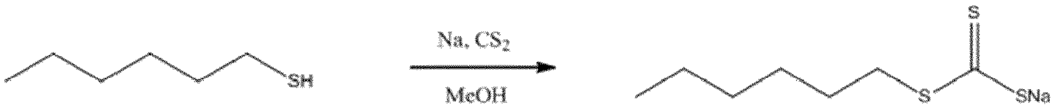
Synthesis 4: *Synthesis of Sodium Hexyltrithiocarbonate*

[0145] The amount of reactants are shown in Table 3b.

Table 3b

Materials	MW	Mass (g)	Moles	Equivalents
Sodium Metal	23.0	9.74	0.423	1.0
1-Hexanethiol	118.2	50.0	0.423	1.0
Carbon Disulfide	76.1	48.3	0.635	1.5

[0146] Sodium in kerosene (Sigma Aldrich) was weighed and submerged in a small beaker of hexane. It was added to 100mL of methanol stirring in a 125mL flask under nitrogen in several chunks over approximately 3 hours. Methanol was added to replace evaporated solvent. Sodium methoxide solution was slowly added via addition funnel to a 500mL round bottom flask containing 1-hexanthiol (Sigma Aldrich) stirring in 50mL methanol. The flask was placed in a cold water bath, and carbon disulfide (Sigma Aldrich) was added slowly via syringe. The reaction mixture immediately turned yellow and evolved heat. The mixture was stirred for approximately 15 minutes then evaporated to dryness under reduced pressure. Product is a bright yellow solid. The reaction is shown below:



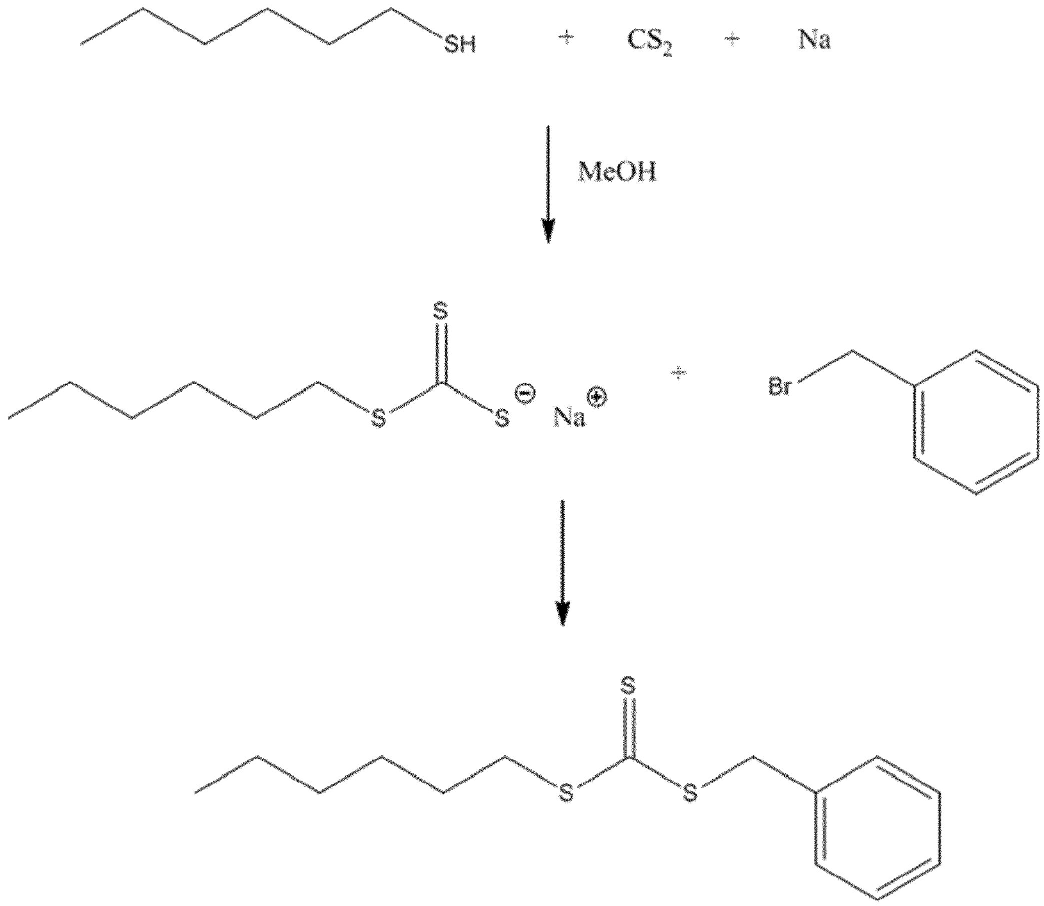
Synthesis 5: *Synthesis of S-benzyl-S'-hexyl-trithiocarbonate*

[0147] The amount of reactants are shown in Table 3c.

Table 3c

Materials	MW	Mass (g)	Moles	Equivalents
Sodium Metal	23.0	1.00	0.0435	1.0
1 -Hexanethiol	118.2	5.14	0.0435	1.0
Carbon Disulfide	76.1	3.64	0.04785	1.1
Benzyl Bromide	171.0	7.44	0.0435	1.0

[0148] Sodium in kerosene (Sigma Aldrich) was added in pieces slowly under nitrogen to 20mL of methanol to form sodium methoxide. This solution was added to a flask containing 1-hexanethiol (Sigma Aldrich) in several aliquots. Carbon disulfide (Sigma Aldrich) was added drop-wise via syringe. The solution turned yellow immediately. The solution was allowed to react for 15 minutes. Benzyl bromide (Sigma Aldrich) was then added dropwise via syringe. A precipitate formed immediately. The reaction was allowed to proceed for two hours. A yellow oil eventually formed at the bottom of the flask. The methanol was roto-vapped off and the product was separated from the sodium salt with deionized water and hexane. The aqueous layer was approximately 50mL and was extracted three times with 50mL of hexane. The hexane was combined, dried over Na2SO4 and evaporated to dryness under pressure. The reaction is shown below.



Preparations 7-8: *Preparation ofPDMA Acrylic Acid*

[0149] DMA was purified *via* vacuum distillation. Acrylic acid (Sigma Aldrich) was used as received. S-benzyl-S'-hexyltrithiocarbonate was prepared according to Procedure 1. Irgacure 819 was dissolved in decanol (10mg/mL). The components were used in the amounts shown in Table 3d, below.

Table 3d

Materials	P7-30% (g)	P8-80% (g)
CTA	0.137	0.144
Ethanol	13.0	11.0
DMA	10.00	3.00
Acrylic Acid	3.12	8.73
Irgacure-819	0.00201	0.00211

[0150] The polymerization solutions were prepared for each of Preparation 5-7 by adding DMA and acrylic acid to an amber 30mL glass jar. Next, ethanol, S-benzyl-S'-hexyltrithiocarbonate (CTA), and Irgacure-819 were added to the monomer and warmed/stirred to ensure homogeneity (CTA to initiator ratio = 100). The amber jar containing the final polymerization solution was sealed with a rubber septum and purged for 20 minutes with N_2 to remove O_2 from the solution. Finally the sealed jar was placed in an N_2 glove-box for storage.

[0151] The polymerization solution was cured under an N_2 atmosphere with 4 standard Phillips TL 20W/03 RS bulbs at intensity of 2.0 mW/cm^2. Prior to curing, the polymerization solution was poured into a 125mm diameter crystallization dish, which was then placed on a reflective glass surface. No increase in viscosity was observed after 40 minutes under light. In each example another dose of Irgacur 819 equal to the initial dose was added to the dish lowering the CTA to initiator ratio to 50 to improve polymerization. The solution was mixed with swirling then exposed to light for another 30 minutes and became extremely viscous.

[0152] After curing, the resulting polymerized material was dissolved in 40mL of ethanol. The solution was stirred overnight then transferred to an addition funnel using 20mL of ethanol to rinse out the crystallization dish. The polymer solution was added drop-wise to vigorously stirring diethyl ether to precipitate product. A 1L flask filled with 800mL of ether was used. The precipitated polymer was dried *in vacuo* for several hours and then subjected to further purification via Soxhlet Extraction with diethyl ether. The polymers were analyzed for MW and MWD via SEC-MALLS.

Examples 13-15 (reference)

[0153] A base reactive mixture having the components listed in Table 4, below was made by mixing the components in the amounts listed with t-amyl alcohol (55 wt% components:45 wt% t-amyl alcohol).

Table 4

Component	**Wt %**
DMA	29.45
Blue HEMA	0.02
Norbloc 7966	2.2
Irgacure 819	0.25
MBA	1.10
SA2	55.98
PVP K90	8.00
Bis-HEAA	3.00

[0154] Separate formulations were made adding 3 mol% of the ionic component listed in Table 5, below. The formulations were stirred on a jar roller for 2 hours, and then filtered. Each reactive mixture was degassed, dosed into molds (Zeonor FC / polypropylene BC) and cured for 5 minutes, at about 55°C, about 2.25 mW/cm^2 intensity, and about 0.2% O_2. The molds were separated by hand. The lenses were released and extracted in 70/30 IPA / DI and finally hydrated in standard packing solution. The lenses were sterilized at 121 °C for 20 minutes. The sterilized lenses were tested for lysozyme and PQ1 uptake.

[0155] Comparative Example 5 were lenses made from the formulation in Table 4 without any ionic components added. Comparative Example 6 lenses were made from the formulation in Table 4 with 3% MAA as the ionic component. Comparative Examples 7 and 8 are made from the formulation in Table 6. The procedure for making the lenses of Comparative Examples 7 and 8 are described below.

Table 5

Ex#	Ionic Specics (mol %)	Ionic Species (mol/gm)	Lysozyme Uptake (μg/lens)	PQ1 uptake (%)	[H2O] (%)
CE5	None	0	5.5 ±0.55	8 ± 3	43 ± 0.1
CE 6	3% MAA	1.33×10^{-4}	143 ± 9	82 ± 1	52 ± 0.2
13	3%ACA1	1.35×10^{-4}	142 ± 10	9 ± 1	53 ± 0.2
14	3% ACA2	1.35×10^{-4}	98 ± 29	7 ± 1	54 ± 0.1
CE7	None	0	5.2 ± 0.2	6 ± 3	37 ± 0.2
CE8	1.5% MAA	6.5×10^{-5}	116 ± 3	100 ± 0	47 ± 0.1

[0156] Comparative Example 6 is an ionic mixed methacrylate (MAA)/methacrylamide (SA2, bisHEAA, DMA, MBA) system. The addition of 3 mol% MAA greatly improved lysozyme uptake compared to Comparative Example 5, which is the same formulation without any ionic component. However, Comparative Example 6 displayed dramatically increased PQ1 uptake. Examples 13 and 14 contain ACA1 and ACA2 as the ionic component, both of which are acrylamides. They also display significantly improved lysozyme uptake, but show no increase in PQ1 uptake compared to Comparative Example 5. The lenses of the disclosure are formed from reaction mixtures comprising the same reactive functionality (in Examples 13-14, acrylamide). This provides a statistical copolymer with the anionic charge evenly distributed throughout the lens. It is believed that the desirable combination of properties results from this consistent distribution of charge throughout the lenses of the disclosure.

[0157] The formulations of Comparative Examples 7-8 contain monomers having methacrylate functionality (mPDMS, HOmPDMS, HEMA) and methacrylamide functionality (DMA). Thus, Comparative Example 8, displays very high PQ-1 uptake (100%).

Comparative Examples 7 and 8

[0158] Comparative Example lenses were formed by mixing the components, in the amounts listed in Table 6 with D3O (23%D3O:77% components). Comparative Example 8 used the same formulation, but with 1.5 mol% MAA added to the formulation.

Table 6

Compound	Wt %	Mole %
mPDMS	27.53	7.8
HOmPDMS	36.07	16.6
TEGDMA	1.33	1.3
DMA	21.31	60.8
HEMA	5.33	11.6
PVP K-90	6.22	1.8-3
Irgacure 819	0.43	0.29
Norbloc 7966	1.78	1.6
Blue HEMA	0.02	0.007

[0159] The formulations were dosed in to molds (Zeonor FC / polypropylene BC) and cured for 5 minutes, at about 55°C, about 2.25 mW/cm^2 intensity, and about 0.2% O_2. The lenses were released and extracted in 70/30 IPA / DI and finally hydrated in standard packing solution. The lenses were sterilized at 121 °C for 20 minutes.

[0160] The lysozyme and PQ1 uptake were measured and are shown in Table 5, above.

Examples 15-20 (reference)

[0161] A base reactive mixture having the components listed in Table 7, below was made by mixing the components in the amounts listed with t-amyl alcohol (55 wt% components:45 wt% t-amyl alcohol).

Table 7

Component	**Wt %**
DMA	30.90
Norbloc	2.00
Irgacure 819	0.125
MBA	1.300
SA2	55.65
PVP K90	7.00
bis-HEAA	3.02

[0162] Formulations were made adding ACA1 as the ionic component in the amounts listed in Table 8, below. Comparative Example 9 was formed from the formulation in Table 7, with no ACA1 added. The formulations were stirred on a jar roller for 2 hours, and then filtered.

[0163] Each reactive mixture was degassed, dosed into molds (Zeonor TuffTec FC / polypropylene BC) and cured for 5 minutes, at about 60°C, about 1.5 mW/cm^2 intensity, and about 0.2% O_2. The molds were separated by hand. The lenses were released and extracted in 70/30 IPA / DI and finally hydrated in standard packing solution. The lenses were sterilized at 121 °C for 20 minutes. The sterilized lenses were tested for water content, lysozyme and PQ1 uptake. The results are shown in Table 8, below.

Table 8

Ex#	[ACA1] (mol %)	[ACA1] (mol/gm)	Lysozyme Uptake (μg/lens)	PQ1 Uptake (%)	[H_2O] %
CE9	0	0	5 ± 1	2 ± 3	40 ± 0.1
15	0.25	1.2×10^{-5}	86 ± 11	4 ± 2	43 ± 0.3
16	0.5	2.4×10^{-5}	150 ± 5	6 ± 1	43 ± 0.2
17	1.0	4.7×10^{-5}	145 ± 7	5 ± 4	46 ± 0.2
18	1.5	7.0×10^{-5}	152 ± 7	6 ± 1	49 ± 0.1
19	3.0	1.4×10^{-4}	151 ± 7	5 ± 4	53 ± 0.2
20	6.0	2.8×10^{-4}	163 ± 5	61 ± 2	62 ± 0.1

[0164] This series shows that a wide range (0.25 to 3 mol %) anionic component can be used to achieve the desired increase in lysozyme uptake without increasing PQ1 uptake or undesirably increasing water content. Example 20 shows undesirable PQ1 uptake. It is believed that even though the charges are evenly distributed throughout the lens copolymer, the concentration is high enough to attract significant quantities of PQ1. These lenses would be undesirable for reusable lenses, but could be suitable for daily disposable lenses which are not cleaned and are generally not contacted with multipurpose solutions.

Comparative Examples 10-13

[0165] A base reactive mixture having the components listed in Table 6, above was made by mixing the components in the amounts listed with D3O (77 wt% components:23 wt% D3O).

[0166] Formulations were made adding MAA as the ionic component in the amounts listed in Table 9, below. The formulations were stirred on a jar roller for 2 hours, and then filtered.

[0167] Each reactive mixture was degassed, dosed into molds (Zeonor TuffTec FC / polypropylene BC) and cured for 5 minutes, at about 60°C, about 1.5 mW/cm^2 intensity, and about 0.4% O_2. The molds were separated by hand. The lenses were released and extracted in 70/30 IPA / DI and finally hydrated in standard packing solution. The lenses were sterilized at 121 °C for 20 minutes. The sterilized lenses were tested for water content, lysozyme and PQ1 uptake. The results are shown in Table 9, below.

Table 9

Ex#	[MAA] (mol %)	[MAA] (mol/gm)	Lysozyme Uptake (μg/lens)	PQ1 Uptake (%)	[H2O] %
CE10	0	0	5 ± 0.2	0.7	38 ± 0.2
CE11	0.5	2.2×10^{-5}	29 ± 3	5	42 ± 0.2
CE12	0.8	3.6×10^{-5}	42 ± 3	36	45 ± 0.1
CE13	1.1	5.1×10^{-5}	67 ± 3	100	46 ± 0.0

[0168] The formulation in Table 9 contains both methacrylate components (HO-mPDMS, HEMA and mPDMS) as well as acrylamide components (DMA). Comparative Examples 10-13 show that such systems cannot provide the desired balance of lysozyme uptake greater than 50 μg/lens and PQ1 uptake of less than about 10%.

Examples 20-24 (reference)

[0169] A base reactive mixture having the components listed in Table 10, below was made by mixing the components in the amounts listed with t-amyl alcohol (65 wt% components:35 wt% t-amyl alcohol).

Table 10

Component	Wt %
DMA	39.41
Norbloc 7966	2.00
Irgacure 819	0.125
MBA	1.00
SA2	49.51
PVP K90	7.95

[0170] Formulations were made adding AMPS as the ionic component in the amounts listed in Table 11, below. The formulations were stirred on a jar roller for 2 hours, and then filtered. Each reactive mixture was degassed, dosed into molds (Zeonor TuffTec FC / polypropylene BC) and cured for 5 minutes, at about 60°C, about 1.9 mW/cm^2 intensity, and about 0.2% O_2. The molds were separated by hand. The lenses were released and extracted in 70/30 IPA / DI and finally hydrated in standard packing solution. The lenses were sterilized at 121°C for 20 minutes. The sterilized lenses were tested for water content, lysozyme and PQ1 uptake. The results are shown in Table 11, below.

Table 11

Ex#	[AMPS] (mol %)	[AMPS] (mol/gm)	Lysozyme Uptake (μg/per lens)	PQ1 Uptake (%)	[H_2O] (wt %)
20	0.25	1.2 x10^{-5}	87±4	4±1	50±0.1
21	0.5	2.5 x10^{-5}	145±2	3±1	53±0.2
22	1.0	5.1 x10^{-5}	143±4	1±1	58±0.1
23	1.4	7.0 x10^{-5}	166±11	6±3	69±0.2
24	3.0	1.4 x 10^{-4}	Not tested	16±3	72±0.1

[0171] This series shows that a wide range (0.25 to 3 mol %) anionic component can be used to achieve the desired increase in lysozyme uptake without increasing PQ1 uptake. Example 24 shows undesirable PQ1 uptake. It is believed that even though the charges are evenly distributed throughout the lens copolymer, the concentration is high enough to attract significant quantities of PQ1. These lenses would be undesirable for reusable lenses, but could be suitable for daily disposable lenses which are not cleaned and are generally not contacted with multipurpose solutions. The lenses of Example 24 were also fragile and displayed an undesirably high water content. Thus, this Example series shows that concentrations of AMPS between about 0.2 and about 1.5 mol% provide a desirable combination of lysozyme and PQ1 uptake, and water content.

Synthesis 4: VINAL

[0172] 4.82 g vinyl chloroformate (Aldrich) was added to 8.19 g β-alanine (Aldrich) dissolved in 74 ml acetonitrile. The mixture was refluxed under nitrogen and with stirring for 2 hours. It was cooled to room temperature for 2 hours, then filtered. The solvent was removed under reduced pressure.

[0173] This crude product was dissolved in 30 ml water and washed three times with ethyl acetate. The combined ethyl acetate fractions were washed with 50 ml water. The solvent was stripped off to yield 4.51 g VINAL as an off-white solid.

Synthesis 5: N-dodecyl-O-vinylcarbamate (DVC)

[0174] 3.0 g dodecylamine (Aldrich), 4.0 g Na_2CO_3 and 30 ml CH_2Cl_2 were placed into a 100 ml round bottomed flask with a stir bar and thermocouple thermometer, and under nitrogen. The flask was placed into a room temperature water bath. 1.9 g vinylchloroformate (Aldrich) was added via a side armed addition funnel. There was a modest exotherm. The mixture was stirred for about 4 hours at room temperature, filtered and washed once with 1.0N HCl and twice with water. It was dried over Na_2SO_4 and the solvent was stripped off to yield the crude product as a mushy solid.

[0175] The crude product was dissolved in a minimal amount of methanol, and precipitated with water. The solvent was removed and the crystals were dried under vacuum to yield 2.2 g product.

Preparation 9: PVP-co-VINAL (2wt%)

[0176] 19.6 g N-vinylpyrrolidone (ACROS, 98%), 0.40 g VINAL and 10 µl 2-hydroxy-2-methylpropiophenone (Aldrich) were combined to form a clear blend. The solution was placed into two 14 mm diameter polypropylene tubes. These tubes were irradiated with UV light from 4 Philips TL 20W/09N fluorescent bulbs for 4 hours in a nitrogen environment. The solid polymer was removed from the tubes and stirred in 150 ml tetrahydrofuran to dissolve. This solution was poured into 700 ml diethyl ether with stirring to precipitate the polymer. The solid was recovered by filtration, redissolved in THF, and reprecipitated with diethyl ether. It was recovered by filtration and dried for 48 hours under vacuum to yield polymer as a soft white solid.

Preparation 10 - PVP-co-VINAL(2wt%)-co-DVC(2wt%)

[0177] The procedure of Preparation 9 was used to form copolymer from 4.8 g N-vinylpyrrolidone, 0.1 g VINAL, 0.1 g DVC and 6 µl 2-hydroxy-2-methylpropiophenone.

Preparation 11 - PVP

[0178] The procedure of Preparation 9 was used to form PVP homopolymer from 10 g N-vinylpyrrolidone and 6 µl 2-hydroxy-2-methylpropiophenone.

Comparative Examples 13-15

[0179] Solutions having a concentration of 1 wt% were formed by adding 1 g of each of the polymers made in Preparations 9-11 in 100 g borate buffered saline solution (pH 7.4) and mixing for 2 hours at 60°C. 3 ml of each solution was placed into each of several vials. One senofilcon A contact lens (ACUVUE OASYS™ BRAND CONTACT LENSES with HYDRACLEAR™ Plus) was placed into each vial. The vials were sealed and autoclaved at 121°C for 30 minutes. The lenses were rinsed in fresh borate buffered saline and tested for contact angle using the sessile drop method. The results are shown in Table 11.

Table 11

	CE14	CE15	CE16
Polymer	PVP-VINAL (2%)	PVP-VINAL(2%)- DVC(2%)	PVP
Contact angle	37 ± 6°C	38 ± 10°C	60 ± 10°C
Lysozyme (µg/lens)	5.75 ± 0.2	5.46±0.12	NM

[0180] Desirable decreases in contact angle were achieved however, the lysozyme uptake was not significantly increased. Comparing Comparative Examples 14 and Example 19, which contained 2-4 mol% anionic monomer to Examples 2-4 , it is believed that increasing the concentration of the anionic monomers in polymers used in Comparative Examples 14 and 15 to at least about 20 mol% and in some cases at least about 30 mol% or greater, will provide the desired lysozyme uptake.

Claims

1. An anionic, silicone hydrogel contact lens comprising in or on said silicone hydrogel at least one statistical copolymer comprising units derived from at least 10 weight% of at least one non-ionic hydrophilic monomer and at least one anionic monomer and wherein said contact lens has a contact angle of about 70° or less, at least about 50 µg/lens lysozyme uptake, and less than about 10% uptake of PQ1 when measured using the "PQ-1 Uptake" method given in the description,
wherein said statistical copolymer is non-reactive and is associated with or entangled in said silicone hydrogel contact lens,
wherein said non-reactive statistical copolymer further comprises a hydrophobic block on at least one terminus,
wherein said hydrophobic block comprises polydialkylsiloxane, polydiarylsiloxane and mixtures thereof.

2. The contact lens of claim 1 wherein said alkyl is selected from C_1-C_4 alkyl.

3. The contact lens of claim 1 wherein said hydrophobic block comprises polydimethylsiloxane or polydiethylsiloxane.

4. The contact lens of claim 1 wherein said hydrophobic block comprises polydimethylsiloxane or polydiethylsiloxane, either of which may be terminated by a C_{1-12} alkyl, C_1-C_4 alkyl, aryl, or methyl, or n-butyl.

5. The contact lens of claim 1 wherein said hydrophobic block comprises between about 6 and about 200 siloxy units.

6. The contact lens of claim 1 wherein said units from said non-ionic hydrophilic monomer and said anionic monomer when polymerized have a degree of polymerization of at least about 300.

7. The contact lens of claim 1 wherein said statistical copolymer comprises about 20 to about 80 mol% units from said anionic monomer or about 20 to about 60 mol% units from said anionic monomer.

8. The contact lens of claim 1 wherein said statistical copolymer comprises about 80 to about 20 mol% units from said non-ionic hydrophilic monomer or about 80 to about 40 mol% units from said non-ionic hydrophilic monomer.

9. The contact lens of claim 1 wherein said statistical copolymer is formed by RAFT polymerization, free radical polymerization, or step growth polymerization.

10. The contact lens of claim 1 wherein said anionic monomer and said non-ionic hydrophilic monomer have the same reactive functionality.

11. The contact lens of claim 10 wherein said anionic monomer and said non-ionic hydrophilic monomer are selected from (meth)acrylamides, or are selected from (meth)acrylates, or are selected from vinyls.

12. The contact lens of claim 1 wherein said lens has less than about 5% uptake of PQ1.

13. The contact lens of claim 1 further comprising a water content of between about 20% and about 70% or between about 25% and about 65%.

14. The contact lens of claim 1 wherein said anionic monomer and said non-ionic hydrophilic monomer have the same reactive functionality and are selected from (meth)acryamides, and optionally wherein said anionic monomer is selected from the group consisting of 3-acrylamidopropionic acid, 4-acrylamidobutanoic acid, 5-acrylamidopentanoic acid, sodium-2-(acrylamido)-2-methylpropane sulphonate, 2-acrylamido-2-methylpropane sulfonic acid and combinations thereof.

15. The contact lens of claim 1 wherein said anionic monomer and said non-ionic hydrophilic monomer have the same reactive functionality and

    (a) wherein said anionic monomer and said non-ionic hydrophilic monomer are selected from (meth)acrylates, and optionally
    wherein said anionic monomer is selected from the group consisting of (meth)acrylic acid, acrylic acid, 3-sulphopropyl (meth)acrylate potassium salt, 3-sulphopropyl (meth)acrylate sodium salt, sulphoethyl methacrylate, and mixtures thereof, or
    wherein said anionic monomer comprises (meth)acrylic acid; or
    (b) wherein said anionic monomer and said non-ionic hydrophilic monomer are selected from vinyls, and optionally wherein said anionic monomer is selected from the group consisting of N-vinyloxycarbonyl-α-alanine, N-vinyloxycarbonyl-β-alanine, 2-vinyl-4,4-dimethyl-2-oxazolin-5-one, vinyl sulphonate sodium salt, vinyl sulphonate salt, and mixtures thereof.

Patentansprüche

1. Anionische Siliconhydrogel-Kontaktlinse, die in oder an dem Silicon-Hydrogel wenigstens ein statistisches Copolymer umfasst, das Einheiten abgeleitet aus wenigstens 10 Gew.-% an wenigstens einem nichtionischen hydrophilen Monomer und wenigstens einem anionischen Monomer umfasst, und wobei die Kontaktlinse einen Kontaktwinkel von etwa 70° oder weniger, wenigstens etwa 50 μg/Linse Lysozymaufnahme und weniger als etwa 10 % Aufnahme von PQ1, wenn gemessen unter Verwendung des in der Beschreibung gegebenen "PQ-1-Aufnahme"-Verfahrens,

aufweist,
wobei das statistische Copolymer nichtreaktiv ist und mit der Siliconhydrogel-Kontaktlinse verbunden oder darin verschlungen ist,
wobei das nichtreaktive statistische Copolymer ferner einen hydrophoben Block an wenigstens einem Terminus umfasst,
wobei der hydrophobe Block Polydialkylsiloxan, Polydiarylsiloxan und Gemische davon umfasst.

2. Kontaktlinse gemäß Anspruch 1, wobei das Alkyl aus C_1-C_4Alkyl ausgewählt ist.

3. Kontaktlinse gemäß Anspruch 1, wobei der hydrophobe Block Polydimethylsiloxan oder Polydiethylsiloxan umfasst.

4. Kontaktlinse gemäß Anspruch 1, wobei der hydrophobe Block Polydimethylsiloxan oder Polydiethylsiloxan umfasst, die jeweils mit einem C_{1-12}Alkyl, C_1-C_4Alkyl, Aryl oder Methyl oder n-Butyl terminiert sein können.

5. Kontaktlinse gemäß Anspruch 1, wobei der hydrophobe Block zwischen etwa 6 und etwa 200 Siloxyeinheiten umfasst.

6. Kontaktlinse gemäß Anspruch 1, wobei die Einheiten aus dem nichtionischen hydrophilen Monomer und dem anionischen Monomer, wenn polymerisiert, einen Polymerisationsgrad von wenigstens etwa 300 aufweisen.

7. Kontaktlinse gemäß Anspruch 1, wobei das statistische Copolymer etwa 20 bis etwa 80 mol-% Einheiten aus dem anionischen Monomer oder etwa 20 bis etwa 60 mol-% Einheiten aus dem anionischen Monomer umfasst.

8. Kontaktlinse gemäß Anspruch 1, wobei das statistische Copolymer etwa 80 bis etwa 20 mol-% Einheiten aus dem nichtionischen hydrophilen Monomer oder etwa 80 bis etwa 40 mol-% Einheiten aus dem nichtionischen hydrophilen Monomer umfasst.

9. Kontaktlinse gemäß Anspruch 1, wobei das statistische Copolymer durch RAFT-Polymerisation, frei radikalische Polymerisation oder Stufenwachstumspolymerisation gebildet ist.

10. Kontaktlinse gemäß Anspruch 1, wobei das anionische Monomer und das nichtionische hydrophile Monomer die gleiche reaktionsfähige Funktionalität aufweisen.

11. Kontaktlinse gemäß Anspruch 10, wobei das anionische Monomer und das nichtionische hydrophile Monomer ausgewählt sind aus (Meth)acrylamiden oder ausgewählt sind aus (Meth)acryalaten oder ausgewählt sind aus Vinylen.

12. Kontaktlinse gemäß Anspruch 1, wobei die Linse weniger als etwa 5 % Aufnahme von PQ1 aufweist.

13. Kontaktlinse gemäß Anspruch 1, ferner umfassend einen Wassergehalt von zwischen etwa 20 % und etwa 70 % oder zwischen etwa 25 % und etwa 65 %.

14. Kontaktlinse gemäß Anspruch 1, wobei das anionische Monomer und das nichtionische hydrophile Monomer die gleiche reaktionsfähige Funktionalität aufweisen und ausgewählt sind aus (Meth)acrylamiden, und gegebenenfalls wobei das anionische Monomer ausgewählt ist aus der Gruppe bestehend aus 3-Acrylamidopropionsäure, 4-Acrylamidobutansäure, 5-Acrylamidopentansäure, Natrium-2-(acrylamido)-2-methylpropansulfonat, 2-Acrylamido-2-methylpropan-sulfonsäure und Kombinationen davon.

15. Kontaktlinse gemäß Anspruch 1, wobei das anionische Monomer und das nichtionische hydrophile Monomer die gleiche reaktionsfähige Funktionalität aufweisen und

a) wobei das anionische Monomer und das nichtionische hydrophile Monomer ausgewählt sind aus (Meth)acrylaten, und gegebenenfalls
wobei das anionische Monomer ausgewählt ist aus der Gruppe bestehend aus (Meth)acrylsäure, Acrylsäure, 3-Sulfopropyl(meth)acrylat-Kaliumsalz, 3-Sulfopropyl(meth)acrylat-Natriumsalz, Sulfoethylmethacrylat und Gemischen davon oder
wobei das anionische Monomer (Meth)acrylsäure umfasst oder
(b) wobei das anionische Monomer und das nichtionische hydrophile Monomer ausgewählt sind aus Vinylen,

und gegebenenfalls wobei das anionische Monomer ausgewählt ist aus der Gruppe bestehend aus N-Vinyloxycarbonyl-α-alanin, N-Vinyloxycarbonyl-β-alanin, 2-Vinyl-4,4-dimethyl-2-oxazolin-5-on, Vinylsulfonat-Natriumsalz, Vinylsulfonatsalz und Gemischen davon.

Revendications

1. Lentille de contact en hydrogel de silicone anionique comprenant, dans ou sur ledit hydrogel de silicone, au moins un copolymère statistique comprenant des motifs dérivés d'au moins 10 % en poids d'au moins un monomère hydrophile non ionique et d'au moins un monomère anionique, et ladite lentille de contact ayant un angle de contact d'environ 70° ou moins, au moins 50 μg/lentille environ d'absorption de lysozyme, et moins d'environ 10 % d'absorption de PQ1 lorsqu'elle est mesurée en utilisant la méthode « Absorption de PQ-1 » donnée dans la description, ledit copolymère statistique étant non réactif et étant associé à ou imbriqué dans ladite lentille de contact en hydrogel de silicone,
   ledit copolymère statistique non réactif comprenant en outre un bloc hydrophobe sur au moins une extrémité, ledit bloc hydrophobe comprenant un poldialkyl-siloxane, un polydiarylsiloxane et des mélanges de ceux-ci .

2. Lentille de contact de la revendication 1 dans laquelle ledit groupe alkyle est choisi parmi les groupes alkyle en C_1-C_4.

3. Lentille de contact de la revendication 1 dans laquelle ledit bloc hydrophobe comprend du polydiméthyl-siloxane ou du polydiéthylsiloxane.

4. Lentille de contact de la revendication 1 dans laquelle ledit bloc hydrophobe comprend du polydiméthyl-siloxane ou du polydiéthylsiloxane, dont chacun peut être terminé par un groupe alkyle en C_{1-12}, alkyle en C_{1-4}, aryle, ou méthyle, ou n-butyle.

5. Lentille de contact de la revendication 1 dans laquelle ledit bloc hydrophobe comprend entre environ 6 et environ 200 motifs siloxy.

6. Lentille de contact de la revendication 1 dans laquelle lesdits motifs issus dudit monomère hydrophile non ionique et dudit monomère anionique lorsqu'ils sont polymérisés ont un degré de polymérisation d'au moins 300 environ.

7. Lentille de contact de la revendication 1 dans laquelle ledit copolymère statistique comprend environ 20 à environ 80 % en moles de motifs issus dudit monomère anionique ou environ 20 à environ 60 % en moles de motifs issus dudit monomère anionique.

8. Lentille de contact de la revendication 1 dans laquelle ledit copolymère statistique comprend environ 80 à environ 20 % en moles de motifs issus dudit monomère hydrophile non ionique ou environ 80 à environ 40 % en moles de motifs issus dudit monomère hydrophile non ionique.

9. Lentille de contact de la revendication 1 dans laquelle ledit copolymère statistique est formé par polymérisation RAFT, polymérisation radicalaire, ou polymérisation par croissance par étapes.

10. Lentille de contact de la revendication 1 dans laquelle ledit monomère anionique et ledit monomère hydrophile non ionique ont la même fonctionnalité réactive.

11. Lentille de contact de la revendication 10 dans laquelle ledit monomère anionique et ledit monomère hydrophile non ionique sont choisis parmi les (méth)acrylamides, ou sont choisis parmi les (méth)acrylates, ou sont choisis parmi les vinyles.

12. Lentille de contact de la revendication 1, ladite lentille ayant moins d'environ 5 % d'absorption de PQ1.

13. Lentille de contact de la revendication 1 comprenant en outre une teneur en eau comprise entre environ 20 % et environ 70 % ou entre environ 25 % et environ 65 %.

14. Lentille de contact de la revendication 1 dans laquelle ledit monomère anionique et ledit monomère hydrophile non ionique ont la même fonctionnalité réactive et sont choisis parmi les (méth)acrylamides, et éventuellement dans laquelle ledit monomère anionique est choisi dans le groupe constitué par l'acide 3-acrylamidopropionique, l'acide

4-acrylamidobutanoïque, l'acide 5-acrylamidopentanoïque, le sulfonate sodique de 2-acrylamido-2-méthylpropane, l'acide 2-acrylamido-2-méthylpropane-sulfonique et les combinaisons de ceux-ci .

15. Lentille de contact de la revendication 1 dans laquelle ledit monomère anionique et ledit monomère hydrophile non ionique ont la même fonctionnalité réactive et

(a) dans laquelle ledit monomère anionique et ledit monomère hydrophile non ionique sont choisis parmi les (méth)acrylates, et éventuellement
dans laquelle ledit monomère anionique est choisi dans le groupe constitué par l'acide (méth)acrylique, l'acide acrylique, le sel potassique de (méth)acrylate de 3-sulfopropyle, le sel sodique de (méth)acrylate de 3-sulfopropyle, le méthacrylate de sulfoéthyle, et les mélanges de ceux-ci, ou
dans laquelle ledit monomère anionique comprend de l'acide (méth)acrylique, ou
(b) dans laquelle ledit monomère anionique et ledit monomère hydrophile non ionique sont choisis parmi les vinyles, et éventuellement dans laquelle ledit monomère anionique est choisi dans le groupe constitué par la N-vinyloxycarbonyl-α-alanine, la N-vinyloxycarbonyl-β-alanine, la 2-vinyl-4,4-diméthyl-2-oxazolin-5-one, le sel sodique de sulfonate de vinyle, un sel de sulfonate de vinyle, et les mélanges de ceux-ci.

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