CLAIMS

1. A method for producing hydrogel contact lenses, comprising the steps of:

(1) obtain a first polymerizable fluid composition and a second polymerizable fluid composition,

wherein the first polymerizable fluid composition comprises at least one photoinitiator and at least one polymerizable material and is free of any photochemically functional compound,

wherein the second polymerizable fluid composition is substantially identical to the first polymerizable fluid composition except that the first polymerizable fluid composition is free of said at least one photochemically functional compound present in the second polymerizable fluid composition,

wherein the second polymerizable fluid composition comprises:

said at least one photoinitiator,

said at least one polymerizable material, and

said at least one photochemically functional compound present in the second polymerizable fluid composition,

wherein the difference between the concentration of said at least one photoinitiator in the first polymerizable fluid composition and the concentration of said at least one photoinitiator in the second polymerizable fluid composition is 5.0% or less,

wherein the difference between the concentration of said at least one polymerizable material in the first polymerizable fluid composition and the concentration of said at least one polymerizable material in the second polymerizable fluid composition is 5.0% or less,

wherein said at least one photochemically functional compound present in the second polymerizable fluid composition is:

a photochromic compound,

a UV/HEVL absorbing compound,

a fluorescent compound,

a color-filtering material for correcting color blindness,

a diffractive material,

a high refractive-index material, or

combinations thereof,

wherein the first polymerizable fluid composition has a first curing time and the second polymerizable fluid composition has a second curing time,

wherein the first and second curing times are determined in photo-rheology study using a visible light having a spectral centroid of 452nm and a total irradiance of 54 mW/cm^2;

(2) obtaining a lens mold,

wherein the lens mold comprises a female mold half having a first molding surface defining the anterior surface of a contact lens to be molded and a male mold half having a second molding surface defining the posterior surface of the contact lens to be molded, and

wherein the female and male mold halves are configured to receive each other such that a mold cavity is formed between the first and second molding surfaces when the mold is closed;

(3) applying an amount of the second polymerizable fluid composition onto a central zone of the first molding surface of the female mold half to form a circular layer of the second polymerizable fluid composition, wherein the circular layer has a diameter of 13.00 mm or less;

(4) irradiating with the visible light at the specified intensity the circular layer of the second polymerizable fluid composition for a time period that is 5% to 75% of the second curing time, to partially crosslink the circular layer of the second polymerizable fluid composition;

(5) dispensing an amount of the first polymerizable fluid composition over the partially-crosslinked circular layer on the central zone of the first molding surface;

(6) closing the female mold half with the male mold half to form a molding assembly comprising the partially crosslinked circular layer immersed in the first polymerizable fluid composition within the mold cavity;

(7) irradiating with the visible light at the specified intensity the molding assembly for a time that is at least 120% of the first curing time to form an unprocessed hydrogel contact lens having a central zone that has a diameter of 13 mm or less, is concentric with the central axis of the unprocessed hydrogel contact lens, and possesses at least one photochemical functionality provided by said at least one photochemically functional compound;

(8) separating the molding assembly into the male and female mold halves, with the unprocessed hydrogel contact lens adhered onto a lens-adhered mold half which is one of the male and female mold halves;

(9) removing the unprocessed hydrogel contact lens from the lens-adhered mold half; and

(10) subjecting the unprocessed hydrogel contact lens to post-molding processes including a hydration process and one or more other processes selected from the

group consisting of extraction, surface treatment, packaging, sterilization, and combinations thereof.

2. The method of claim 1,

wherein the first and second polymerizable fluid compositions are capable of forming a non-silicone hydrogel, and

wherein said at least one polymerizable material is a first monomer mixture comprising:

(a) at least one first hydrophilic vinylic monomer selected from the group consisting of at least one hydroxyl-containing vinylic monomer, N,N-dimethylarylamide, N-vinylpyrrolidone, at least one methylene-containing pyrrolidone monomer, and combinations thereof, and

(b) at least one component selected from the group consisting of at least one non-silicone vinylic crosslinker, a non-silicone hydrophobic vinylic monomer, a UV-absorbing vinylic monomer, and combinations thereof.

3. The method of claim 2, wherein said at least one polymerizable material comprises at least 50% by weight of at least one hydroxyl-containing vinylic monomer, relative to the total weight of all polymerizable materials present in the first polymerizable fluid composition.

4. The method of claim 1,

wherein the first and second polymerizable fluid compositions are capable of forming a non-silicone hydrogel, and

wherein said at least one polymerizable material is a reactive mixture comprising:

(a) one or more water-soluble non-silicone prepolymers, and

(b) optionally, at least one component selected from the group consisting of a hydrophilic vinylic monomer, a non-silicone vinylic crosslinker, a non-silicone hydrophobic vinylic monomer, a UV-absorbing vinylic monomer, and combinations thereof.

5. The method of claim 1,

wherein the first and second polymerizable fluid compositions are capable of forming a silicone hydrogel, and

wherein said at least one polymerizable material is a second monomer mixture comprising:

(a) at least one silicone-containing vinylic monomer,

(b) at least one polysiloxane vinylic crosslinker, at least one non-silicone vinylic crosslinker, or both,

(c) at least one second hydrophilic vinylic monomer, and

(d) optionally, at least one component selected from the group consisting of a non-silicone hydrophobic vinylic monomer, a UV-absorbing vinylic monomer, and combinations thereof,

wherein said at least one second hydrophilic vinylic monomer comprises at least one hydrophilic (meth)acrylamido monomer having 3 to 8 carbon atoms, at least one hydrophilic (meth)acryloxy monomer, at least one hydrophilic N-vinyl amide monomer, at least one methylene-containing pyrrolidone monomer, at least one vinyl ether monomer, at least one allyl ether monomer, at least one phosphorylcholine-containing vinylic monomer, N-2-hydroxyethyl vinyl carbamate, N-vinyloxycarbonyl-β-alanine, N-vinyloxycarbonyl-α-alanine, or combinations thereof,

wherein said at least one silicone-containing vinylic monomer comprises:

(i) at least one silicone-containing vinylic monomer containing a tris(trialkylsiloxy)silyl group and one sole ethylenically-unsaturated group selected from the group consisting of a (meth)acryloyloxy group, a (meth)acryloylamino group, a vinyl carbonate group, and a vinylcarbamate group;

(ii) at least one silicone-containing vinylic monomer containing a bis(trialkylsilyloxy)-alkylsilyl group and one sole ethylenically-unsaturated group selected from the group consisting of a (meth)acryloyloxy group, a (meth)acryloylamino group, a vinyl carbonate group, and a vinylcarbamate group;

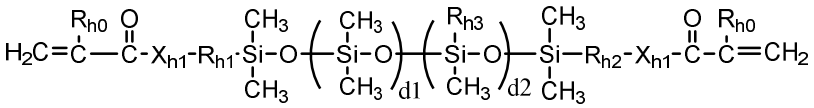
(iii) at least one silicone-containing vinylic monomer containing:

a) one sole ethylenically-unsaturated group selected from the group consisting of a (meth)acryloyloxy group, a (meth)acryloylamino group, a vinyl carbonate group, and a vinylcarbamate group, and

b) a polysiloxane chain having 2 to 30 siloxane units and terminated with an alkyl, hydroxyalkyl or methoxyalkyl group; or

(iv) combinations thereof.

6. The method of claim 5, wherein the second monomer mixture comprises at least one polysiloxane vinylic crosslinker of formula (H)



(H)

in which:

d1 is an integer of from 30 to 500 and d2 is an integer of from 1 to 75, provided that

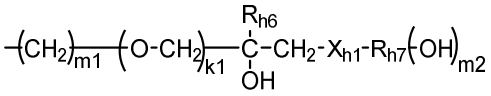
d2/d1 is from 0.035 to 0.15;

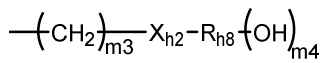
X_{h1} is O or NR_{hN} in which R_{hN} is hydrogen or C_1-C_{10}-alkyl;

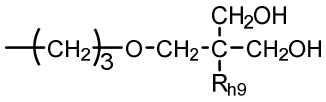
R_{h0} is hydrogen or methyl;

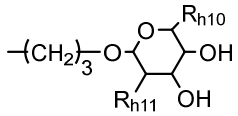
R_{h1} and R_{h2} independently of each other are a substituted or unsubstituted C_1–C_{10} alkylene divalent radical or a divalent radical of $–R_{h4}–O–R_{h5}–$ in which R_{h4} and R_{h5} independently of each other are a substituted or unsubstituted C_1–C_{10} alkylene divalent radical;

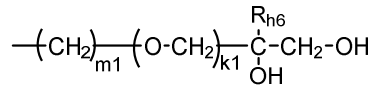
R_{h3} is a monovalent radical of any one of formula (H-a) to (H-e)


(H-a)


(H-b)


(H-c)


(H-d)


(H-e)

k1 is zero or 1; m1 is an integer of 2 to 4; m2 is an integer of 1 to 5; m3 is an integer of 3 to 6; m4 is an integer of 2 to 5;

R_{h6} is hydrogen or methyl;

R_{h7} is a C_2-C_6 hydrocarbon radical having (m2+1) valencies;

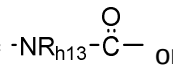
R_{h8} is a C_2-C_6 hydrocarbon radical having (m4+1) valencies;

R_{h9} is ethyl or hydroxymethyl;

R_{h10} is methyl or hydroxymethyl;

R_{h11} is hydroxyl or methoxy;

X_{h1} is a sulfur linkage of –S– or a tertiary amino linkage of $–NR_{h12}–$ in which R_{h12} is C_1-C_1 alkyl, hydroxyethyl, hydroxypropyl, or 2,3-dihydroxypropyl; and

X_{h2} is a linkage of or  in which R_{h13} is hydrogen or C_1-C_{10} alkyl.

7. The method of claim 5 or 6, wherein the second monomer mixture comprises:

(i) at least one polysiloxane vinylic crosslinker having one sole polydiorganosiloxane segment and two terminal ethylenically-unsaturated groups selected

from the group consisting of (meth)acryloyloxy groups, (meth)acryloylamino groups, vinyl carbonate groups, vinylcarbamate groups; and/or

(ii) at least one chain-extended polysiloxane vinylic crosslinker having at least two polydiorganosiloxane segments and a covalent linker between each pair of polydiorganosiloxane segments and two terminal ethylenically-unsaturated groups selected from the group consisting of (meth)acryloyloxy groups, (meth)acryloylamino groups, vinyl carbonate groups, vinylcarbamate groups.

8. The method of any one of claims 5 to 7, wherein the sum of the amounts of components (a), (b) and (c) in the second monomer mixture is at least 60% by weight relative to the total weight of all polymerizable materials present in the second monomer mixture.

9. The method of any one of claims 1 to 8, wherein said at least one polymerizable material comprises:

(i) at least one non-silicone vinylic crosslinker selected from the group consisting of ethyleneglycol di-(meth)acrylate, diethyleneglycol di-(meth)acrylate, triethyleneglycol di-(meth)acrylate, tetraethyleneglycol di-(meth)acrylate, glycerol di-(meth)acrylate, 1,3-propanediol di-(meth)acrylate, 1,3-butanediol di-(meth)acrylate, 1,4-butanediol di-(meth)acrylate, glycerol 1,3-diglycerolate di-(meth)acrylate, ethylenebis[oxy(2-hydroxypropane-1,3-diyl)] di-(meth)acrylate, bis[2-(meth)acryloxyethyl] phosphate, trimethylolpropane di-(meth)acrylate, and 3,4-bis[(meth)acryloyl]tetrahydrofuan, diacrylamide (i.e., N-(1-oxo-2-propenyl)-2-propenamide), dimethacrylamide (i.e., N-(1-oxo-2-methyl-2-propenyl)-2-methyl-2-propenamide), N,N-di(meth)acryloyl-N-methylamine, N,N-di(meth)acryloyl-N-ethylamine, N,N'-methylene bis(meth)acrylamide, N,N'-ethylene bis(meth)acrylamide, N,N'-dihydroxyethylene bis(meth)acrylamide, N,N'-propylene bis(meth)acrylamide, N,N'-2-hydroxypropylene bis(meth)acrylamide, N,N'-2,3-dihydroxybutylene bis(meth)acrylamide, 1,3-bis(meth)acrylamide-propane-2-yl dihydrogen phosphate (i.e., N,N'-2-phophonyloxypropylene bis(meth)acrylamide), piperazine diacrylamide (or 1,4-bis(meth)acryloyl piperazine), tetraethyleneglycol divinyl ether, triethyleneglycol divinyl ether, diethyleneglycol divinyl ether, ethyleneglycol divinyl ether, triallyl isocyanurate, triallyl cyanurate, trimethylopropane trimethacrylate, pentaerythritol tetramethacrylate, bisphenol A dimethacrylate, and combinations thereof;

(ii) at least one non-silicone hydrophobic vinylic monomer which comprises at least one C_1-C_8 alkyl (meth)acrylate, at least one C_5-C_{16} cycloalkyl (meth)acrylate, at least one aryl methacrylate, (meth)acrylonitrile, at least one fluorine-containing acrylic monomer, at least one vinyl alkanoate, at least one vinyloxyalkane, at least one substituted or

unsubstituted styrene, vinyl toluene, vinyl chloride, vinylidene chloride, 1-butene, or combinations thereof;

(iii) at least one UV-absorbing vinylic monomer; or

(iv) combinations thereof.

10. The method of any one of claims 1 to 9, wherein the circular layer of the second polymerizable fluid composition is irradiated for a time period that is from 5% to 65% of the second curing time.

11. The method of any one of claims 1 to 10, wherein said at least one photochemically functional compound comprises at least one polymerizable UV/HEVL-absorbing compound.

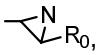
12. The method of any one of claims 1 to 10, wherein said at least one photochemically functional compound comprises at least one polymerizable fluorescent compound.

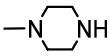
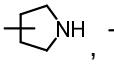
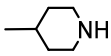
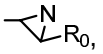
13. The method of any one of claims 1 to 10, wherein the second polymerizable fluid composition comprises at least one photochromic compound that comprises a naphthopyran, an indeno-fused naphthopyran, a heterocyclic ring-fused naphthopyrian, a benzopyran, a phenanthropyran, a quinopyran, a quinolinopyran, a fluoroanthenopyran, an anthracene-fused pyran, a tetracene-fused pyran, a spiro(benzindoline) naphthopyran, a spiro(indoline)naphthopyran, a spiro(indoline)benzopyran, a spiro(indoline)quinopyran, a spiro(indoline)pyran, a naphthoxazine, a spirobenzopyran, a spirobenzothiopyran, a naphthacenedione, a benzoxazine, a spirooxazine, a naphthoxazine, a spiro(benzindoline)naphthoxazine, a spiro(indoline)naphthoxazine, a spiro(indoline)pyrido-benzoxazine, a spiro(indoline)benzoxazine, a spiro(benzindoline) benzoxazine, a spiro(benzindoline)pyridobenzoxazine, a spiro(indoline) fluoranthenoxazine, a spiro(indoline)-quinoxazine, a spiropiperidine-naphthopyran, a piro(indoline)pyronobenzoxazinone, a benzospiropyran, a naphthospiropyran, a spirobenzoxazine-pyrrolopyridine, a spironaphthoxazine-pyrrolopyrridine, a spiro-oxazepin-benzoxazine, a spiro-oxazepin-naphthoxazine, a spiro(indoline) benzothiazoloxazine, a spiro(indoline)benzopyrroloxazine, a spiro(indoline)quinazolino-oxazine, a spiro(indoline)-anthracenobenzoxazine, a benzofurobenzopyran, a benzothienobenzopyran, a naphthofurobenzopyran, a benzopyrano-fused naphthopyran, a spiro(isoindoline)-naphthoxazine, a spiro(isoindoline)benzoxazine, or a mixture thereof.

14. The method of claim 13, wherein said at least one photochromic compound is polymerizable and comprises an ethylenically-unsaturated group.

15. The method of claim 14,

wherein said at least one photochromic compound is a coupling reaction product of a reactive (meth)acrylamido or (meth)acryloxy monomer having a first reactive functional group and a reactive photochromic compound having a second reactive functional group in the absence or presence of a coupling agent under coupling reaction,

wherein the first reactive functional group is selected from the group consisting of –COCl, –COBr, –COOH, –NHR$_{N2}$, –NCO, –OH, –CHO, , , or ,

wherein the second reactive functional group is selected from the group consisting of –COOH, –NHR$_{N2}$, , , , –NCO, –OH, –SH, –CHO, , , or ,

wherein R_0 is hydrogen or methyl and R_{N2} is hydrogen, a linear or branched C_1-C_{15} alkyl, cyclohexyl, cyclopentyl, a substituted or unsubstituted phenyl, or a substituted- or unsubstituted-phenyl-C_1-C_6 alkyl, and

wherein the reactive (meth)acrylamido or (meth)acryloxy monomer is selected from the group consisting of (meth)acryloyl halides of CH_2=CH–COX or CH_2=CCH_3–COX in which X= Cl or Br, N-hydroxysuccinimide ester of (meth)acrylic acid, glycidyl (meth)acrylate, isocyanato- C_2-C_6 alkyl (meth)acrylate, amino–C_2-C_6 alkyl (meth)acrylamide, C_1-C_6 alkylamino–C_2-C_6 alkyl (meth)acrylamide, (meth)acrylic acid, C_2-C_4 alkylacrylic acid, N-2-acrylamidoglycolic acid, 3-(acryloylxy)propanoic acid, C_2-C_6 hydroxylalkyl (meth)acrylate, C_2-C_6 hydroxyalkyl (meth)acrylamide, an azlactone-containing vinylic monomer, an aziridinyl C_1-C_{12} alkyl (meth)acrylate, acrolein, methacrolein, crotonaldehyde, and combinations thereof.