

Description

Contact lenses are generally produced by one of three general techniques - lathing, molding or spin-casting. Each technique has its advantages and disadvantages. For instance, lathing involves forming the anterior and posterior portion of the lens by cutting both surfaces from a disc of lens material. This technique is the most costly of the three manufacturing techniques but affords certain design freedoms not otherwise readily available using molding or spin casting..

Molding and spin-casting form the lens with few further processing steps. In both techniques, the anterior and posterior surfaces are formed in one step. Molding accomplishes this result by providing two mold surfaces which define the anterior and posterior of the lens. The spin casting process forms the anterior surface by providing a mold surface and the posterior surface by the forces generated by spinning the liquid monomer. Both techniques allow lower cost production of contact lenses than lathing due to the lower labor contact required to produce finished lenses.

However in both the spin-casting technique and in the molding technique, the lens adheres to the mold surface. This phenomena is an inevitable consequence of the spin-casting and the molding process and obvious because of the chemical interaction between the mold surface and the monomer mixture as the monomer is polymerized. Normally, this lens/mold interaction is overcome by hydrating the lens material which has the effect of weakening the interaction between mold and lens and also gently pulls the lens from the mold. Thus, the lens is in its soft form when it is first removed from the mold.

Cast contact lenses are rigorously inspected after casting to insure their optical performance and to avoid cosmetic effects and edge defects. These inspections are difficult to accomplish with soft lenses and requires significant labor to accomplish. Xerogel lenses (nonhydrated or hard lenses) are more readily inspected. Therefore, the cost of producing hydrogel lenses could be reduced by releasing hard lenses from the mold, inspecting the hard lenses and then hydrating the lenses until they had become hydrogels.

Various attempts have been made to release soft contact lenses from molds in their dry state. For instance, U.S. Patent No. 2,542,286 teaches adding "lubricant" to optical devices made from resins.

U.S. Patent No. 3,171,869 describes a method for releasing plastic lenses which comprises polymerizing the resin to a gel like state at 25°C to 125°C and then heating the gel to 125°C to 235°C until the hardened resin is formed.

U.S. Patent 3,944,637 teaches using a specific comonomer mixture to achieve release from the mold. These three patents describe methods for releasing lenses from glass molds. Modern contact lens manufacturing is done in plastic molds as is evident from the teachings of U.S. Patent 4,155,962 which teaches a method for releasing a xerogel lens from a mold container by applying force against the sides of the mold.

U.S. Patent 4,159,292 teaches a method for controlling the release of contact lenses from plastic molds by providing the mold material with an internal lubricant.

U.S. Patent No. 4,534,916 teaches adding surfactants to the comonomer to produce lenses with improved surface quality lenses. The use of such surfactants decreases the number of surface defects on the lens. The examples show that the lenses were removed from the molds in spin casting.

The present invention relates to an improved method for manufacturing contact lenses, the improvement being related to releasing lenses from their molds without hydrating the lens to a hydrogel state. This improvement is accomplished by providing the monomer or comonomer mixture to be cast with from 0.001 to 3 weight percent of release agent which is a mixture of at least one hydrophilic nonreactive polymer and at least one lipophilic compound. Upon polymerization of the lens in the mold to its hard xerogel state, the lens can be released in its nonhydrated form by distorting the plastic mold.

Thus, Applicants have found that they can produce hard xerogel lenses which can be dry released from plastic molds by simply including in the monomer or comonomer mixture used to make the contact lens a mixture of a hydrophilic polymer and a lipophilic compound. Lenses made using this method are substantially equivalent to lenses made by state of the art methods with respect to their physical characteristics, but they have the advantage of having simplified post casting processing into finished lenses due to the fact that they are still in their hard state.

The mixture of hydrophilic polymer and lipophilic compound is effective in accomplishing effective dry release in the range of 0.001 to 3 weight percent based on the weight of the monomer or comonomer to be polymerized. The preferred range is 0.1 to 1.0 weight percent. It has been found that the ratio of hydrophilic polymer to lipophilic compound by weight can preferably range from 5/1 to 1/5. Most preferably, the ratio has been 4/1 to 1/1 by weight.

The hydrophilic polymers which have proven effective in the present invention include polyethylene glycol and polypropylene glycol. The average molecular weights of these hydrophilic polymers is preferably in the range of 200 to 8,000, with the most preferred molecular weights being in the 2,000 to 4,000 range.

Other hydrophilic polymers may be used in the method of the invention as long as they do not react in the polymerization process used to form the lens material and their solubility parameters are sufficiently close to the monomer or comonomer mixture and the final polymer to avoid heterophasing that would cause opaque contact lenses.

Examples of such other hydrophilic polymers include poly(N-vinyl pyrrolidinone), poly(hydroxyethyl methacrylate), poly acrylamide, poly(dimethyl acrylamide), poly(vinyl alcohol), poly(hydroxypropyl methylcellulose), poly caprolactam, polyoxymethylene (formaldehyde), polyacrylonitrile, poly(hexamethylene adipamide), cellulose, poly(ethylene terephthalate), poly methacrylic acid, poly itaconic acid, poly glyceryl methacrylate, poly(N-vinyl oxazolidone) and polymethacryloylglycine.

The lipophilic compounds used in the present invention are preferably chosen from the class of fatty acids and fatty alcohols. Specific examples include stearic acid, oleic acid, lauric acid, linoleic acid, linolenic acid, palmitic acid, myristic acid, palmitic acid, arachidic acid, lignoceric acid, and their alcohol functional analogs. Other lipophilic compounds can be used as long as they are relatively unreactive to the polymerization process employed to use the lens and they are used in small enough amounts to avoid heterophasing out of the monomer mixture during polymerization so as to cause opaque contact lenses.

Examples of such other lipophilic compounds include tetradecane, hexadecane, naphthalene, 1-chlorohexadecane, 1-hydroxy hexadecane and n-hexadecyl ether.

The types of contact lens materials which may be used in the present invention are the whole range of "hydrogel materials". This includes polyhydroxyethyl methacrylate- and polyvinyl pyrrolidinone-based systems as well as the many copolymer formulations which employ hydroxyethyl methacrylate and/or vinylpyrrolidinone.

The use in accordance with the present invention of the combination of hydrophilic polymer with lipophilic compound to improve contact lens production can be employed in the spin-casting techniques and in molding techniques which employ two piece molds such as the techniques disclosed in U.S. Patent No. 3,881,683; U.S. Patent No. 4,197,266; U.S. Patent No. 4,121,896; or G.B. Patent App. 2,185,933; and in other casting and molding techniques known to be useful to form contact lenses.

The following examples illustrate the invention.

EXAMPLES

Example 1 - Dry Release of PHEMA Lenses as Practiced In the Prior Art

A typical contact lens comonomer mixture of about 85 wt percent 2-hydroxyethylmethacrylate, 15 weight percent glycerin, 0.35 weight percent ethylene glycol dimethacrylate and 0.18 weight percent of the free radical catalyst benzoin methyl ether (BME) was spun cast into a contact lens using a plastic mold. Upon curing the lenses in the lens molds were dry released by distorting the plastic mold.

Less than 1% of the lens released without breaking or without other surface damage which rendered them commercially and clinically unacceptable.

Example 2 - Attempted Dry Release of Lenses with Hydrophilic Polymer Added

To the prepolymer mixture used in Example 1, various amounts of hydrophilic polymer were added. For instance, where 0.5 wt% of polypropylene glycol (m.w. of about 4000) was added to this mixture, and lenses were cast, there was improved dry-release of the lens. However, there remained a tendency of the lens to adhere to the center of the mold still.

Example 3 - Dry Release of Lenses Cast Per Method of the Invention

All lens comonomer mixtures were the same as used in Examples 1 and 2 except 0.25 weight parts of the following mixture were added to the comonomer mixture:

- A. 0.06 wt. pts. stearic acid/0.19 wt. pts. polyethylene glycol m.w. 3000;
- B. 0.06 wt. pts. succinic acid/0.19 wt. pts. polyethylene glycol m.w. 3000;
- C. 0.06 wt. pts. stearic acid/0.19 wt. pts. polyethylene glycol m.w. 4000; and
- D. 0.06 wt. pts. stearic acid/0.19 wt. pts. polyethylene glycol (m.w. 3300).

Lenses were cast in PVC molds and dry released. The lenses were then inspected per structural commercial methods and evaluated. Only lenses which released without breaking were inspected.

	<u>Mixture</u>	<u>Lenses Cast</u>	<u>Lenses Inspected</u>	<u>Lenses Found Acceptable</u>
5	A	25	19	10
	B	25	15	9
	C	25	24	19
10	D	23	23	23

This showed significant improvements over the lenses cast per Examples 1 and 2 which had effective yield rates of 0. Higher yield rates than state-of-the-art were obtained with polyethylene glycol alone-but required significantly higher concentration of the polymer.

As can be appreciated, the addition of the hydrophilic polymer and the lipophilic moiety increased the yield dramatically of dry releasing lenses.

Claims

1. A method for manufacturing contact lenses wherein monomer or comonomer mixture is placed into a mold cavity and subjected to polymerization conditions to form a polymerized shape, characterized in that a mixture of at least one nonreactive hydrophilic polymer and at least one lipophilic compound is included in the monomer or comonomer mixture as a release agent in amount from 0.001 to 3 weight percent of the monomer or comonomer mixture.
2. A method according to Claim 1, wherein the monomer or comonomers to be polymerized is(are) selected from N-vinyl pyrrolidone, 2-hydroxyethyl methacrylate, methylmethacrylate, methacrylic acid and acrylic acid.
3. A method according to Claim 1 or Claim 2, wherein said hydrophilic polymer is selected from polyethylene glycol with average molecular weights between 200 and 8,000 and polypropylene glycol with average molecular weights between 200 and 8,000.
4. A method according to any preceding claim, wherein said lipophilic compound is selected from oleic acid, linoleic acid, linolenic acid, palmitic acid, lauric acid, myristic acid, palmitic acid, stearic acid, arachidic acid and lignoceric acid.
5. A method according to any preceding claim, wherein said amount of release agent is 0.1 to 1.0 weight percent of the monomer or comonomer mixture.
6. A method according to any preceding claim, wherein the ratio of hydrophilic to lipophilic compound by weight is from 5:1 to 1:5.
7. A method according to Claim 6, wherein said ratio is from 4:1 to 1:1 by weight.

Patentansprüche

1. Verfahren zur Herstellung von Kontaktlinsen, bei dem ein Monomer oder eine Comonomermischung in einen Hohlraum einer Form gegeben wird und Polymerisationsbedingungen unterworfen wird, um eine polymerisierte Form zu bilden, dadurch gekennzeichnet, daß dem Monomer oder der Comonomermischung eine Mischung von mindestens einem nicht reaktiven hydrophilen Polymer und mindestens einer lipophilen Verbindung als Trennmittel in einer Menge von 0,001 bis 3 Gew.% des Monomers oder der Comonomermischung beigelegt wird.
2. Verfahren nach Anspruch 1, bei dem das zu polymerisierende Monomer oder die zu polymerisierenden Comonomere ausgewählt wird bzw. werden aus N-Vinylpyrrolidon, 2-Hydroxyethylmethacrylat, Methyl-

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2. Verfahren nach Anspruch 1, bei dem das zu polymerisierende Monomer oder die zu polymerisierenden Comonomere ausgewählt wird bzw. werden aus N-Vinylpyrrolidon, 2-Hydroxyethylmethacrylat, Methyl-



methacrylat, Methacrylsäure und Acrylsäure.

3. Verfahren nach Anspruch 1 oder 2, bei dem das hydrophile Polymer ausgewählt wird aus Polyethylenglykol mit durchschnittlichen Molekulargewichten zwischen 200 und 8 000 und Polypropylenglykol mit durchschnittlichen Molekulargewichten zwischen 200 und 8 000.
4. Verfahren nach einem der vorhergehenden Ansprüche, bei dem die lipophile Verbindung ausgewählt wird aus Ölsäure, Linolsäure, Linolensäure, Palmitolsäure, Laurinsäure, Myristinsäure, Palmitinsäure, Stearinsäure, Arachinsäure (Erdnußsäure) und Lignocerinsäure.
5. Verfahren nach einem der vorhergehenden Ansprüche, bei dem die Menge an Trennmittel 0,1 bis 1,0 Gew.% des Monomers oder der Comonomermischung beträgt.
6. Verfahren nach einem der vorhergehenden Ansprüche, bei dem das Gewichtsverhältnis von hydrophiler zu lipophiler Verbindung 5:1 bis 1:5 beträgt.
7. Verfahren nach Anspruch 6, bei dem das Gewichtsverhältnis 4:1 bis 1:1 beträgt.

Revendications

1. Procédé de fabrication de lentilles de contact, le monomère ou le mélange de comonomères étant placé dans une cavité de moule et soumis à des conditions de polymérisation pour donner une forme polymérisée, caractérisé en ce qu'un mélange d'au moins un polymère hydrophile non réactif et d'au moins un composé lipophile est introduit dans le monomère ou le mélange de comonomères comme agent de détachement à raison de 0,001 à 3% en poids du monomère ou du mélange des comonomères.
2. Procédé selon la revendication 1, dans lequel le monomère ou les comonomères à polymériser est choisi (ou sont choisis) parmi la N-vinyl-pyrrolidone, le méthacrylate de 2-hydroxyéthyle, le méthacrylate de méthyle, l'acide méthacrylique et l'acide acrylique.
3. Procédé selon la revendication 1 ou la revendication 2, le polymère hydrophile étant choisi parmi le polyéthylène glycol avec une poids moléculaire moyen compris entre 200 et 8000 et le propylène glycol avec des poids moléculaires moyens compris entre 200 et 8000.
4. Procédé selon une quelconque des revendications précédentes, le composé lipophile étant choisi parmi l'acide oléique, l'acide laurique, l'acide linoléique, l'acide palmitolique, l'acide myristique, l'acide palmitique, l'acide arachidique, l'acide lignocérique.
5. Procédé selon l'une quelconque des revendications précédentes, la quantité d'agent de séparation étant de 0,1 à 1,0% en poids du mélange de monomère ou de comonomères.
6. Procédé selon l'une quelconque des revendications précédentes, le rapport du composé hydrophile sur le composé lipophile allant de 5 : 1 à 1 : 5 en poids.
7. Procédé selon la revendication 6, ce rapport allant de 4 : 1 à 1 : 1 en poids.

