

Method for producing contact lenses

The present invention is related to an improved method for producing contact lenses.

BACKGROUND OF THE INVENTION

Contact lenses can be manufactured economically in large numbers by a conventional full-mold process involving disposable molds, the examples of which are disclosed in, for example, PCT patent application no. WO/87/04390, in EP-A 0 367 513 or in U.S. Patent No. 5,894,002. In a conventional molding process, a predetermined amount of a polymerizable or crosslinkable material typically is introduced into a disposable mold comprising a female (concave) mold half and a male (convex) mold half. The female and male mold halves cooperate with each other to form a mold cavity having a desired geometry for a contact lens. Normally, a surplus of polymerizable or crosslinkable material is used so that when the male and female halves of the mold are closed, the excess amount of the material is expelled out into an overflow area adjacent to the mold cavity. The polymerizable or crosslinkable material remaining within the mold is polymerized or cross-linked by means of actinic radiation (e.g., UV irradiation, ionized radiation, microwave irradiation or by means of heating. Both the starting material in the mold cavity and the excess material in the overflow area are thereby hardened. After curing, the lens is removed from the mold.

However, when the curing is completed, strong adherence between the mold and the lens occurs. In addition to this adhesion, the male and female mold halves are sealed tight as if a vacuum is created in the mold. In order to remove the lens, both mold halves must be separated first by a mechanical force. Due to the presence seal between the male and female mold halves after curing, an extra force is need to force separation of the mold halves from each other. Such extra force may cause lens damages, such as, fracture, tear etc. and thereby can have adverse impacts on the product yield and lens quality.

Therefore, it would be beneficial to provide an improved process in which minimal force is required to separate mold halves so as to minimize lens damages resulted from the forced separation of mold halves.

SUMMARY OF THE INVENTION

The invention provide a method for producing contact lenses. The method comprises: providing a mold including a first mold half having a first molding surface and a second mold half having a second molding surface, wherein the first and second mold halves are configured to receive each other such that a mold cavity is formed between the first and second molding surfaces, wherein one of the first and second mold halves has a collar that encircles the other mold half to provide a seal between the two mold halves when the mold is closed; dispensing a specific amount of a polymerizable lens-forming material into one of the mold halves; mating the mold halves to close the mold; polymerizing said polymerizable material located between the two mold halves, thereby forming a molded contact lens; applying a small force directly to at least one area of the collar at an angle of less than about 50 degrees relative to the normal direction of the collar in that area, thereby distorting the collar and breaking the seal between the two mold halves; and opening the mold.

The invention also provides an apparatus for demolding contact lenses from molds, the apparatus comprising: a tempering oven, a feeding guide, a mold-opening device, and a mold-pushing device, wherein the feeding guide feeds continuously or on-demand a plurality of closed molds into the mold-opening device, wherein each closed mold includes a first mold half having a first molding surface and a second mold half having a second molding surface, wherein the first and second mold halves are configured to receive each other such that a mold cavity is formed between the first and second molding surfaces, wherein one of the first and second mold halves has a collar that encircles the other mold half to provide a seal between the two mold halves when the mold is closed, wherein each mold contains a molded lens within the mold cavity, wherein the mold-pushing device pushes each mold into the mold-opening device in a lock-in position where the mold-pushing device applies a small force directly onto at least one area of the collar at an angle of less than about 50 degrees relative to the normal direction of the collar in the force-receiving area to cause a slight deformation, thereby breaking vacuum seal between the first and second mold halves so that the mold-opening device is capable of separating the first and second mold halves from each other with a reduced force.

The present invention provides the foregoing and other features, and the advantages of the invention will become further apparent from the following detailed description of the presently

preferred embodiments, read in conjunction with the accompanying figures. The detailed description and figures are merely illustrative of the invention and do not limit the scope of the invention, which is defined by the appended claims and equivalents thereof.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a cross-sectional view of a mold according to a preferred embodiment of the invention.

FIG. 2 illustrates schematically a process of decreasing separation force required for separating the male and female mold halves of a lens-forming mold according to a preferred embodiment of the invention.

FIG. 3a schematically illustrates an apparatus for performing a method of the invention.

FIG. 3b schematically illustrates actions of the mold-opening device of the apparatus shown in FIG. 3a.

DESCRIPTION OF PREFERRED EMBODIMENTS

Reference now will be made in detail to the embodiments of the invention, one or more examples of which are set forth below. Each example is provided by way of explanation of the invention, not limitation of the invention. In fact, it will be apparent to those skilled in the art that various modifications and variations can be made in the present invention without departing from the scope of the invention. For instance, features illustrated or described as part of one embodiment, can be used on another embodiment to yield a still further embodiment. Thus, it is intended that the present invention cover such modification and variations as come within the scope of the appended claims and their equivalents. Other objects, features and aspects of the present invention are disclosed in or are obvious from the following detailed description. It is to be understood by one of ordinary skill in the art that the present discussion is a description of exemplary embodiments only, and is not intended as limiting the broader aspects of the present invention.

Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. Generally, the nomenclature used herein and the laboratory procedures are well known and commonly employed in the art. Conventional methods are used for these procedures, such as those provided in the art and various general references. Where a term is provided in the singular, the inventors also contemplate the plural of that term.

FIGs. 1 schematically illustrates a preferred mold 100 used in the methods and apparatus of the invention. The mold 100 comprises a female mold half 1 and male mold half 2.

The male mold half 2 comprises a base 61, a substantially cylindrical body 25 which extends upward from base 61, a posterior molding surface defining the posterior (concave) surface of a molded contact lens, and an annular shoulder 65 which surrounds the posterior molding surface. The posterior molding surface protrudes outward from the top of body 25. The annular shoulder 65 shown is flat. It is understood that the annular shoulder 65 can have any suitable surface, such as, e.g., a tilted surface.

The female mold half 1 comprises a base 51, a substantially cylindrical body 15 which extends upward from base 51, an anterior molding surface defining the anterior (convex) surface of a molded contact lens, and a collar 4. The anterior molding surface recesses downward from the top of the body 15. Collar 4 (or up-protruding flange) is preferably integral part of the female mold half 1 and protrudes upward from the top of the body 15. A circumferential groove (or recess) 11 is formed on top of the body 15 between the anterior molding surface and functions as an overflow for any excess unpolymerized lens-forming material.

The term "collar" as used herein refers to a peripheral circular part which protrude upward from the top of body of one of the two mating mold halves. A collar can be attached to or preferably integral part of that mold half and which can encircle the other mold half to provide a tight seal between the two mold halves. It is understood that the collar can be provided on either of the male and female mold halves.

The female mold half 1 and a male mold half 2 are configured to receive each other such that a contact lens forming cavity 12 is formed between the anterior and posterior molding

surfaces. The collar 4 encircles the body 25 of the male mold half 2 to provide a tight seal 5 between the female and male mold halves when the mold is closed. Typically, there is no lens material in the seal.

Preferably, the male mold half is subjected to corona treatment prior to its use in order for the molded contact lens to adhere preferentially to the male mold half when opening the mold. Such pre-treatment is described in U.S. Patent No. 5,894,002, herein incorporated by reference in its entirety. It will readily be understood by one skilled in the art that, instead of the male mold half 2, the female mold half 1 can also be pre-treated, which has the result that the contact lens subsequently adheres to the female mold half 1, and the female mold half 1 with the contact lens located therein then has to be further processed.

In operation, mold halves 1 and 2 can be first injection molded from a plastic resin in an injection molding apparatus, as well known to a person skilled in the art. A specific amount of a polymerizable lens-forming material is typically dispensed into the female mold half 1 by means of a dispensing device and then the male mold half 2 is put on and the mold 100 is closed (FIG. 1). As the mold 100 closes, any excess unpolymerized lens-forming material is pressed into an overflow 11 provided on the female mold half 1.

Subsequently, the closed mold 100 containing the polymerizable lens-forming material is subjected to actinic irradiation (e.g., UV radiation), at least in the region of the lens forming cavity 12. For this purpose, at least one of the mold halves is transparent to the actinic radiation (e.g., UV light) at least in the region of the molding surface. Thus, at least the polymerizable lens-forming material in the lens forming cavity 12 is polymerized. It is also possible for any polymerizable lens-forming material in the overflow 11 to be polymerized. This is advantageous in the respect that, when the mold is opened, the excess polymerized lens-forming material then remains in the overflow 11 of the female mold half 1, while the contact lens adhering to the male mold half 2 can be removed and further processed together with male mold half 2.

Before being opened, the mold together with the contact lens CL inside it is placed while still closed in a tempering oven for tempering and is tempered for a time at a temperature of approximately 120°C, whereby any stresses in the material are relieved and the polymerization is finally completed.

Subsequently, a small force can be applied directly onto at least one area of the collar 4 of the female mold half at an angle of less than about 50 degrees, preferably less than about 40 degrees, more preferably less than about 30 degrees, even more preferably less than about 10 degrees, most preferably less than about 5 degrees (i.e., in a direction substantially normal to the collar) relative to the normal direction of the collar in the force-receiving area to break the seal between the mold halves, as shown in FIG. 2. The lens-forming cavity 12 is sealed with the collar 4 of the female mold half 1 and the male mold half 1. Typically, there is no lens material in the seal. A small amount of force can distort the collar 4 of the female mold half 1 and then the seal can be easily broken. Various ways of applying a small force to the collar 14 can be performed. For example, a small force is applied to two opposite small areas on the collar 14 at an angle of less than about 5 degrees (i.e., in a direction substantially normal to the collar) relative to the normal direction of the collar in each force-receiving area by any mechanical means known to a person skilled in the art. Alternatively, a small force can be applied to one small area on one side of the collar 14 at an angle of less than about 5 degrees (i.e., in a direction substantially normal to the collar) relative to the normal direction of the collar in each force-receiving area, while holding the mold in position (e.g., a locking position) or while stopped by a stopper located on one side opposite to the side onto which the small force is applied directly, by any mechanical means known to a person skilled in the art. By breaking the seal between the two mold halves of a mold before opening the mold, any vacuum effect, which is generated during polymerization of the polymerizable lens-forming material in the mold, can be released and therefore the force required to open the mold can be decreased. As such, lens damages occurred during mold opening can be minimized.

After breaking the seal between the mold halves, the mold is opened, the molded contact lens CL adhering to the male mold half 2, while excess lens-forming material, on the other hand, remains in the overflow 11 of the female mold half 1.

The molded contact lens CL adhering to the male mold half 2 is then passed to a hydration device where the contact lens CL is detached from the male mold half 2 and hydrated. Any hydration device can be used in the invention.

In another aspect, the invention provides an apparatus for demolding contact lenses from molds, the apparatus comprising: a feeding guide, a mold-opening device, and a mold-

pushing device, wherein the feeding guide feeds continuously or on-demand a plurality of closed molds into the mold-opening device, wherein each closed mold includes a first mold half having a first molding surface and a second mold half having a second molding surface, wherein the first and second mold halves are configured to receive each other such that a mold cavity is formed between the first and second molding surfaces, wherein one of the first and second mold halves has a collar that encircles the other mold half to provide a seal between the two mold halves when the mold is closed, wherein each mold contains a molded lens within the mold cavity, wherein the mold-pushing device pushes each mold into the mold-opening device in a lock-in position where the mold-pushing device applies a small force directly onto at least one area of the collar at an angle of less than about 50 degrees, preferably less than about 40 degrees, more preferably less than about 30 degrees, even more preferably less than about 10 degrees, most preferably less than about 5 degrees (i.e., in a direction substantially normal to the collar) relative to the normal direction of the collar in the force-receiving area to cause a slight deformation, thereby breaking vacuum seal between the first and second mold halves so that the mold-opening device is capable of separating the first and second mold halves from each other with a reduced force. As used herein, the term "a reduced force" is intended to describe that a force required to open an mold after breaking the seal between the two mold halves of the mold before opening the mold is smaller than a force required to open an mold without breaking the seal between the two mold halves of the mold before opening the mold. A person skilled in that art knows well how to determine a force required to open a mold.

FIG. 3a schematically illustrate a preferred apparatus for performing a method of the invention. Such apparatus can be implemented in a lens production environment, especially in an automatic product process. Each closed mold 100 (shown in Figures 1-2) with a molded lens CL therein is loaded into a feeding guide 31 in which molds drop one by one to the bottom of the feeding guide 31. A sharp edge pusher (or blade) 37 pushes each mold into a jaw assembly (or mold-opening device) 35 in a proper position or lock-in position (i.e., sliding into the jaws and stopped by a stopper 40). The stopper preferably has a sharp edge 41 which is in contact with a small area of the collar of each closed mold 100 at an angle normal to the collar in the small area. It is understood that the stopper 40 and/or pusher 37 can have any non-sharp edge. Once the mold is in proper position, the sharp edge pusher (or blade) 37 applies a small force directly onto, for example, a small side area, opposite to the stopper 40, of the collar of each closed mold at an angle of less than about 5 degrees

relative to the normal direction of the collar in the force-receiving area to cause a slight deformation of the collar, thereby breaking the "vacuum" seal between the male half 1 and female mold half 2. The pusher 37 is driven by a cylinder 39 (e.g., air cylinder). The force applied to the mold assembly can be adjusted via cylinder stroke, stopper position, and/or cylinder line pressure. After the seal is broken, no force or minimal force is needed to separate the male and female mold halves. The male and female mold halves are separated by the mold opening device 35 (FIG. 3b). Preferably, the mold opening device 35 includes a first part 35a and a second part 35b, each part having holding means (e.g., jaws, slots, or the like) for holding one of the mold halves and being pivotally coupled to a support 36 so that the first and second parts 35a and 35b can move pivotally in a synchronized manner to separate the mold halves 1 and 2 as shown in FIG. 3b. After mold opening, the molded contact lens CL preferably adhering to the male mold half 2 is then passed to a hydration device where the contact lens CL is detached from the male mold half 2 and hydrated in a hydration device (not shown).

Feeding guide shown in Figure 3 is installed vertically. As used herein, the term "vertically" is intended to describe that the feeding guide is at a right angle (90 degrees) related to the production floor. Under gravity, each mold will drop, preferably one by one, to the bottom of the feeding guide. However, the feeding guide can also be installed at any other desired angles (to the production floor), for example, such as, 30 degrees, 45 degrees or 60 degrees, instead of 90 degrees shown in Figure 3. The feeding guide can also be installed horizontally (in relation to the production floor). Under this circumstance, the feeding guide can have a transporting means known to a person skilled in the art for transporting each closed mold into a mold-opening device.

It is also understood that the mold-opening device can have any configurations known to a person skilled in the art for performing the function of separating two mold halves from each other.

It is further understood that methods of manufacturing mold halves for cast molding a contact lens are generally well known to those of ordinary skill in the art. The process of the present invention is not limited to any particular method of forming a mold half. In fact, any method of forming a mold half can be used in the present invention. However, for illustrative

purposes, the above discussion has been provided as one embodiment of forming mold halves that can be used in accordance with the present invention.

A "polymerizable lens-forming material" refers to a material which can be polymerized and/or crosslinked by actinic radiation to form a contact lens. A lens-forming material can be any materials known to a skilled artisan. For example, a polymerizable lens-forming material can be a fluid composition (i.e., a solution or a solvent-free liquid or melt at a temperature below 60°C) comprising one or more prepolymers, one or more monomers, one or more macromers, or combinations thereof. A lens-forming material can further include other components, such as a photoinitiator, a visibility tinting agent, UV-blocking agent, photosensitizers, and the like. Preferably, a polymerizable lens-forming material used in the present invention can form a hydrogel material.

A "hydrogel material" refers to a polymeric material which can absorb at least 10 percent by weight of water when it is fully hydrated. Generally, a hydrogel material is obtained by polymerization or copolymerization of at least one hydrophilic monomer in the presence of or in the absence of additional monomers and/or macromers. Exemplary hydrogels include, but are not limited to, poly(vinyl alcohol) (PVA), modified polyvinylalcohol (e.g., as nelfilcon A), poly(hydroxyethyl methacrylate), poly(vinyl pyrrolidone), PVAs with polycarboxylic acids (e.g., carbopol), polyethylene glycol, polyacrylamide, polymethacrylamide, silicone-containing hydrogels, polyurethane, polyurea, and the like. A hydrogel can be prepared according to any methods known to a person skilled in the art.

Various embodiments are evident. Although one mold (FIG. 1) is illustrated, the invention is in no way limited to this specific mold. A person skilled in the art can readily determine other molds for which the invention has applicability.

Claims

1. A method for producing contact lenses, comprising:
 - (a) providing a mold including a first mold half having a first molding surface and a second mold half having a second molding surface, wherein the first and second mold halves are configured to receive each other such that a mold cavity is formed between the first and second molding surfaces, wherein one of the first and second mold halves has a collar that encircles the other mold half to provide a seal between the two mold halves when the mold is closed;
 - (b) dispensing a specific amount of a polymerizable lens-forming material into one of the mold halves; mating the mold halves to close the mold;
 - (c) polymerizing said polymerizable material located between the two mold halves, thereby forming a molded contact lens;
 - (d) tempering the closed mold with the molded contact lens therein in a tempering oven;
 - (e) applying a small force directly to at least one area of the collar at an angle of less than about 50 degrees relative to the normal direction of the collar in the force-receiving area to distort the collar, thereby breaking the seal between the two mold halves; and
 - (f) opening the mold.
2. The method of claim 1, wherein the small force is applied directly to at least one area of the collar at an angle of less than about 30 degrees relative to the normal direction of the collar in the force-receiving area.
3. The method of claim 1, wherein the small force is applied to two opposite small areas on the collar at an angle of less than about 50 degrees relative to the normal direction of the collar in each force receiving area.
4. The method of claim 1, comprising pre-treating the first or second molding surface to render the molded contact lens preferentially adhered to the pre-treated molding surface when opening the mold.

5. The method of claim 4, wherein the pre-treated molding surface is the molding surface of the second mold half which is a male mold half.
6. The method of claim 1, wherein the small force is applied directly to one small area on one side of the collar while the mold being held in a locking position or while being stopped by a stopper located on one side opposite to the side onto which the small force is applied directly.
7. The method of claim 6, wherein the small force is applied directly to the small area at an angle of less than about 30 degrees relative to the normal direction of the collar in the force-receiving small area.
8. An apparatus for demolding contact lenses from molds in a method according to claim 1, the apparatus comprising:
 - a tempering oven,
 - a feeding guide,
 - a mold-opening device, and
 - a mold-pushing device,wherein the feeding guide feeds continuously or on-demand a plurality of closed molds, one by one, into the mold-opening device, wherein each closed mold includes a first mold half having a first molding surface and a second mold half having a second molding surface, wherein the first and second mold halves are configured to receive each other such that a mold cavity is formed between the first and second molding surfaces, wherein one of the first and second mold halves has a collar that encircles the other mold half to provide a seal between the two mold halves when the mold is closed, wherein each mold contains a molded lens within the mold cavity, wherein the mold-pushing device pushes each mold into the mold-opening device in a lock-in or stop position where the mold-pushing device applies a small force directly onto an area of the collar at an angle of less than about 50 degrees relative to the normal direction of the collar in the force-receiving area to cause a slight deformation, thereby breaking vacuum seal between the first and second mold halves so that the mold-opening device is capable of separating the first and second mold halves from each other with a reduced force.

9. The apparatus of claim 8, wherein the mold-pushing device is capable of applying a small force directly to at least one area of the collar at an angle of less than about 30 degrees relative to the normal direction of the collar in the force-receiving area.
10. The apparatus of claim 8, wherein the small force applied to the mold in step (e) of the method according to claim 1 is adjusted via cylinder stroke, stopper position, and/or cylinder line pressure.