

(19) World Intellectual Property Organization
International Bureau



(43) International Publication Date
11 June 2009 (11.06.2009)

PCT

(10) International Publication Number
WO 2009/073076 A1

(51) International Patent Classification:
B29D 11/00 (2006.01)

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(21) International Application Number:
PCT/US2008/012649

(81) Designated States (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IS, JP, KE, KG, KM, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RS, RU, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(22) International Filing Date:
10 November 2008 (10.11.2008)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
60/992,884 6 December 2007 (06.12.2007) US
12/259,794 28 October 2008 (28.10.2008) US

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MT, NL, NO, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).

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Published:
— with international search report

(54) Title: IMPROVED OPHTHALMIC LENS RELEASE

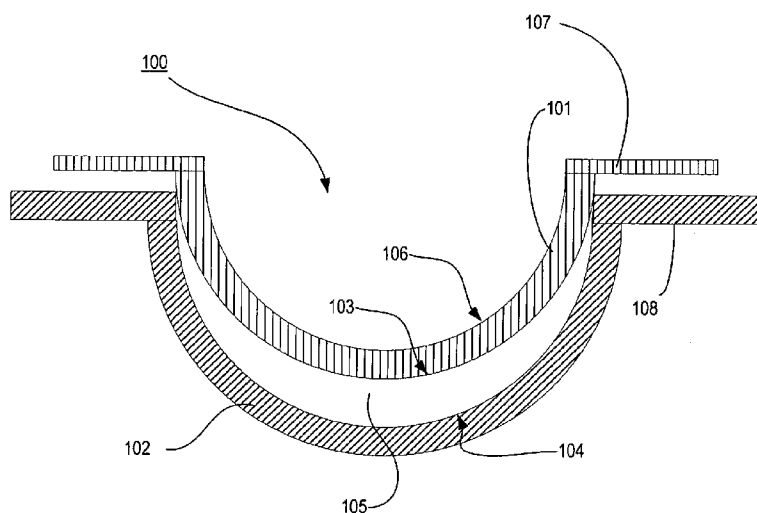


FIG. 1

(57) Abstract: This invention discloses improved mold parts for ophthalmic lenses fashioned from a first thermal plastic resin compounded with a second thermal plastic resin resulting in a thermal plastic compound with a deionized water contact angle that is greater than the deionized water contact angle of either the first thermal plastic resin or the second thermal plastic resin. The mold parts can be used in manufacturing processes, such as, for example: continuous, in-line or batched processes.

WO 2009/073076 A1

IMPROVED OPHTHALMIC LENS RELEASE

This application is a non-provisional filing of a provisional application, U.S. Serial
5 No. 60/992,884, filed on December 6, 2007.

FIELD OF USE

This invention describes molds and ophthalmic lenses formed with the molds and a surface energy differential therebetween.

BACKGROUND

10 Soft contact lenses are popular and often more comfortable to wear than contact lenses made of hard materials. Malleable contact lenses made of silicone based hydrogels can be manufactured by forming a lens in a multi-part cast mold where the combined parts form a topography consistent with the desired final lens. A first mold part can include a convex portion that corresponds with a back curve of an ophthalmic
15 lens and a second mold part can include a concave portion that corresponds with a front curve of the ophthalmic lens.

A typical cast mold process involves depositing a monomer material in a cavity defined between optical surfaces of opposing mold parts. The mold parts are brought together to shape the lens formulation according to desired lens parameters. The lens
20 formulation is cured, for example by exposure to heat and light, thereby forming a lens.

Following cure, the mold parts are separated, a process sometimes referred to as demolding. In some instances, demolding can result in a tear or chip in the formed lens. Typically, the demold process results in the formed lens remaining adhered to one of the mold portions. It is sometimes difficult and time consuming to release the
25 formed lens from the mold part to which the lens has adhered. In particular, some silicone based hydrogel contact lenses are difficult to release in aqueous hydration solutions.

It is desirable therefore to have improved mold materials and processes to facilitate contact lens release in aqueous solutions.

30

SUMMARY

Accordingly, the present invention includes improved molds and processes useful in the release of an ophthalmic lens from a plastic mold part used to cast the lens.

- 5 A mold material can be used with one or more additives which increase the contact angle of the mold material and facilitate lens release from the mold part.

- According to the present invention, a lens forming mixture is cured in a cavity of a desired shape formed by two or more plastic mold parts. At least one of the plastic mold parts is molded from a material with an additive or a combination of plastic mold materials that effectively increased the mold part contact angle and facilitated lens release from the mold part.
- 10

- Embodiments can include at least one of the mold parts being transparent to polymerization initiating radiation such that a polymerizable lens forming mixture can be deposited in the cavity and the mold part and polymerizable composition can be exposed to polymerization initiating radiation.
- 15

- Embodiments can also include methods of producing an ophthalmic lens by dispensing an uncured lens formulation onto a surface of a mold part with a contact angle increased by the use of an additive or combination of mold materials. The ophthalmic lens can include, for example, a silicone hydrogel formulation or a hydrogel formulation. Specific examples can include a lens formed from: aquafilcon A, balafilcon A, and lotrafilcon A, genfilcon A, lenefilcon A, narafilcon A, polymacon and galyfilcon A, and senofilcon A.
- 20

DESCRIPTION OF THE DRAWINGS

- FIG. 1 illustrates a mold assembly according to some embodiments of the present invention.
- 25

FIG. 2 illustrates a flow chart of exemplary steps that can be executed while implementing some embodiments of the present to create a mold part.

FIG. 3 illustrates a flow chart of exemplary steps that can be executed while implementing some embodiments of the present to create an ophthalmic lens.

FIG. 4 illustrates a chart with exemplary data indicating contact angle properties of ophthalmic lens molds fashioned from thermoplastic resins and additives or compounds of thermoplastic resins.

DETAILED DESCRIPTION OF THE INVENTION

5 The present invention includes molds and methods for making an ophthalmic lens. According to some embodiments of the present invention, at least one part of a multi-part mold that is used in the manufacture of an ophthalmic lens, is injection molded from a primary thermal plastic resin (hereinafter sometimes referred to as “TPR”) compounded with one or more of: an additive and a higher contact angle
10 secondary TPR, to increase the contact angle of the mold material and also decrease the release time of a lens formed in the mold.

 According to the present invention the addition of an additive to a TPR mold part material that increases the contact angle of one or both of the BC and FC mold parts, facilitates release of a silicone hydrogel lens when the mold and lens are exposed
15 to an aqueous solution. Compounding a TPR mold material with a second TPR to increase the contact angle of a resultant mold part also facilitates the release of a silicone lens during exposure to an aqueous solution.

 Generally, contact angle is the angle at which a droplet of liquid and a vapor interface meet a solid surface, although a contact angle may also be measured between
20 combinations of liquids and vapors. Contact angle is determined by interactions across interfaces formed. Most often the concept is illustrated with a small liquid droplet resting on a flat horizontal solid surface. The contact angle plays the role of a boundary condition. A contact angle can be measured by various methods using a contact angle goniometer.

25 One method of measuring a contact angle includes the static sessile drop method. The sessile drop method is measured by a contact angle goniometer using an optical subsystem to capture the profile of a pure liquid on a solid substrate. The angle formed between the liquid/solid interface and the liquid-vapor interface is the contact angle. Automated systems employ high resolution cameras and software to capture
30 and analyze the contact angle. Manual systems can include use of a microscope optical system with a back light.

Dynamic sessile drop methods are similar to the static sessile drop but require the drop to be modified. A common type of dynamic sessile drop study determines the largest contact angle possible without increasing its solid/liquid interfacial area by adding volume dynamically. A maximum angle is the advancing angle. Volume is removed to produce the smallest possible angle, the receding angle. The difference between the advancing and receding angle is the contact angle hysteresis.

Another method of measuring contact angle includes the Dynamic Wilhelmy method wherein average advancing and receding contact angles are calculated on solids of uniform geometry. Wetting force on the solid is measured as the solid is immersed in or withdrawn from a liquid of known surface tension.

Still another method of measuring contact angle includes the Single-fiber Wilhelmy method which applies single fibers to measure advancing and receding contact angles.

Generally, a surface with a contact angle larger than 90° can be considered hydrophobic. A surface with contact angle lower than 90° can be considered hydrophilic. Ophthalmic lens mold materials according to the present invention will typically have a contact angle of DI water of over 90° .

One or both mold parts utilized to form an ophthalmic lens is injection molded from a TPR with an additive or other mechanism to increase the contact angle. Injection molding apparatus will typically include precision tooling that has been machined from a metal, such as, for example, brass, stainless steel or nickel or some combination thereof. Typically, tooling is fashioned in a desired shape and machined or polished to achieve precision surface quality. The precision surface in turn increases the quality of a mold part injection molded therefrom.

In some preferred embodiments, mold parts are fashioned from a thermoplastic polyolefin with an additive to produce single use cast molds with increased contact angle which reduces the adhesive force between a cured lens and mold parts used to fashion the lens, and is therefore conducive to the manufacture of ophthalmic lenses. Advantages of utilizing molds comprising a thermoplastic polyolefin material with an additive which results in a higher contact angle include a diminished number of lens

defects, such as holes, chips and tears resulting from demold; and also improved release from a mold part in which it is formed.

In still other embodiments, it has been discovered that a polypropylene mold material with a first DI water contact angle can be combined with one or more cyclic olefin polymers (COP), or cyclic olefin copolymer (COP), or one or more alicyclic polymers, with a second lower DI water contact angle and result in a compounded mold material with a DI water contact angle higher than either the first contact angle of the polypropylene or the second contact angle of the COP. In addition, the compounded mold material including the polypropylene and the COP provided improved performance in terms of lens release from a mold part fashioned from the compound as compared to a mold part fashioned from one or the other constituents of the compound. Specific embodiments and examples are discussed further below.

Lenses

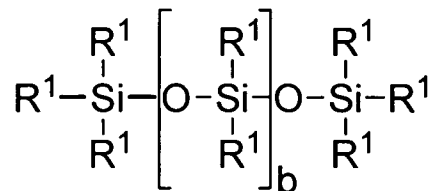
As used herein "lens" refers to any ophthalmic device that resides in or on the eye. These devices can provide optical correction or may be cosmetic. For example, the term lens can refer to a contact lens, intraocular lens, overlay lens, ocular insert, optical insert or other similar device through which vision is corrected or modified, or through which eye physiology is cosmetically enhanced (e.g. iris color) without impeding vision.

As used herein, the term "lens forming mixture" refers to a mixture of materials that can react, or be cured, to form an ophthalmic lens. Such a mixture can include polymerizable components (monomers), additives such as UV blockers and tints, photoinitiators or catalysts, and other additives one might desire in an ophthalmic lens such as a contact or intraocular lens.

In some embodiments, a preferred lens type can include a lens that includes a silicone containing component. A "silicone-containing component" is one that contains at least one [-Si-O-] unit in a monomer, macromer or prepolymer. Preferably, the total Si and attached O are present in the silicone-containing component in an amount greater than about 20 weight percent, and more preferably greater than 30 weight percent of the total molecular weight of the silicone-containing component. Useful silicone-containing components preferably comprise polymerizable functional groups

such as acrylate, methacrylate, acrylamide, methacrylamide, vinyl, N-vinyl lactam, N-vinylamide, and styryl functional groups.

Suitable silicone containing components include compounds of Formula I



5

where

R^1 is independently selected from monovalent reactive groups, monovalent alkyl groups, or monovalent aryl groups, any of the foregoing which may 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, alkoxy, 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 a monovalent reactive group, and in some embodiments between one and 3 R^1 comprise monovalent reactive groups.

As used herein "monovalent reactive groups" are groups that can undergo free radical and/or cationic polymerization. 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-vinyl lactams, N-vinylamides, C_{2-12} alkenyls, C_{2-12} alkenylphenyls, C_{2-12} alkenyl naphthyls, C_{2-6} alkenylphenyl C_{1-6} alkyls, O-vinyl carbamates and O-vinyl carbonates. 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.

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.

In one embodiment b is zero, one R¹ is a monovalent reactive group, and at least 3 R¹ are selected from monovalent alkyl groups having one to 16 carbon atoms, and in another embodiment from monovalent alkyl groups having one to 6 carbon atoms.

Non-limiting examples of silicone components of this embodiment include 2-methyl-

5 ,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

10 3-methacryloxypropylpentamethyl disiloxane.

In another embodiment, b is 2 to 20, 3 to 15 or in some embodiments 3 to 10; at least one terminal R¹ comprises a monovalent reactive group and the remaining R¹ are selected from monovalent alkyl groups having 1 to 16 carbon atoms, and in another embodiment from monovalent alkyl groups having 1 to 6 carbon atoms. In yet another

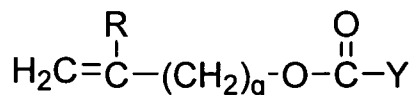
15 embodiment, b is 3 to 15, one terminal R¹ comprises a monovalent reactive group, the other terminal R¹ comprises a monovalent alkyl group having 1 to 6 carbon atoms and the remaining R¹ comprise monovalent alkyl group having 1 to 3 carbon atoms. Non-limiting examples of silicone components of this embodiment include (mono-(2-hydroxy-3-methacryloxypropyl)-propyl ether terminated polydimethylsiloxane (400-
20 1000 MW)) ("OH-mPDMS"), monomethacryloxypropyl terminated mono-n-butyl terminated polydimethylsiloxanes (800-1000 MW), ("mPDMS").

In another embodiment b is 5 to 400 or from 10 to 300, both terminal R¹ comprise monovalent reactive groups and the remaining R¹ are independently selected from monovalent alkyl groups having 1 to 18 carbon atoms which may have ether
25 linkages between carbon atoms and may further comprise halogen.

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 and preferably between about 20 and 70%wt silicone containing components based on total weight of reactive monomer components from which the polymer is made.

30 In another embodiment, one to four R¹ comprises a vinyl carbonate or carbamate of the formula:

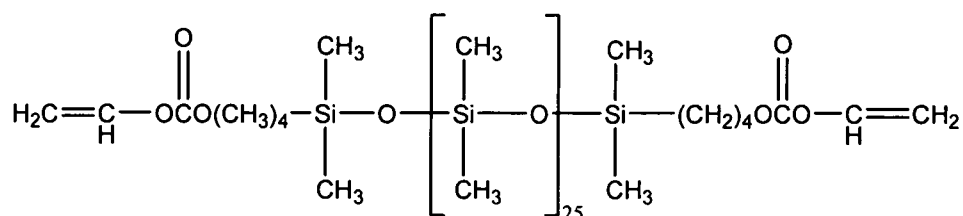
Formula II



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.

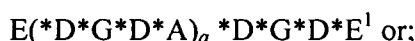
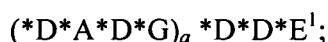
- 5 The silicone-containing vinyl carbonate or vinyl carbamate monomers specifically include: 1,3-bis[4-(vinylloxycarbonyloxy)but-1-yl]tetramethyl-disiloxane; 3-(vinylloxycarbonylthio) propyl-[tris (trimethylsiloxy)silane]; 3-[tris(trimethylsiloxy)silyl] propyl allyl carbamate; 3-[tris(trimethylsiloxy)silyl]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



Where biomedical devices with modulus below about 200 are desired, only one R¹ shall comprise a monovalent reactive group and no more than two of the remaining R¹ groups will comprise monovalent siloxane groups.

- 15 Another class of silicone-containing components includes polyurethane macromers of the following formulae:

Formulae IV-VI



wherein:

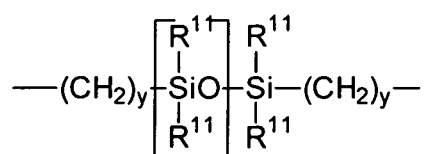
D denotes an alkyl diradical, an alkyl cycloalkyl diradical, a cycloalkyl diradical, an aryl diradical or an alkylaryl diradical having 6 to 30 carbon atoms,

- 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;

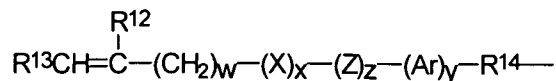
A denotes a divalent polymeric radical of formula:



Formula VII

R¹¹ 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 E¹ independently denotes a polymerizable unsaturated organic radical represented by formula:

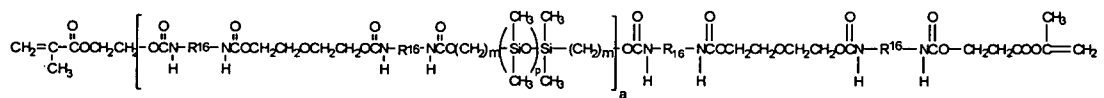
Formula VIII



wherein: R¹² is hydrogen or methyl; R¹³ is hydrogen, an alkyl radical having 1 to 6 carbon atoms, or a —CO—Y—R¹⁵ radical wherein Y is —O—, Y—S— or —NH—;
 10 R¹⁴ 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.

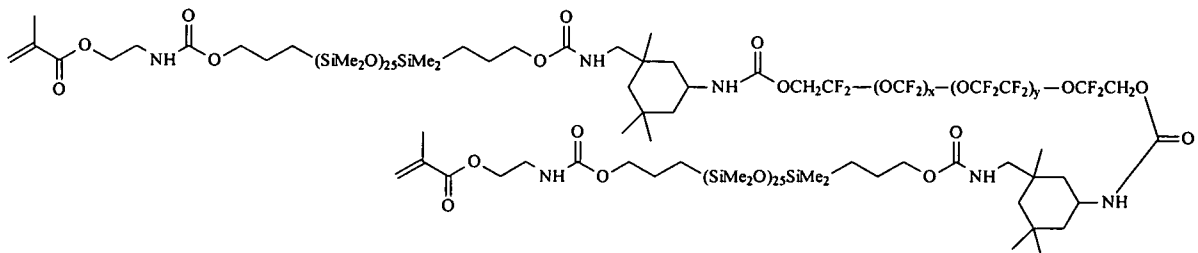
A preferred silicone-containing component is a polyurethane macromer represented by the following formula:

15 Formula IX



wherein R¹⁶ 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 X



Other silicone containing components suitable for use in this invention include macromers containing polysiloxane, polyalkylene ether, diisocyanate, polyfluorinated hydrocarbon, polyfluorinated ether and polysaccharide groups; polysiloxanes with a polar fluorinated graft or side-group having a hydrogen atom attached to a terminal difluoro-substituted carbon atom; hydrophilic siloxanyl methacrylates containing ether and siloxanyl linkages and crosslinkable monomers containing polyether and polysiloxanyl groups. Any of the foregoing polysiloxanes can also be used as the silicone containing component in this invention..

Molds

Referring now to Fig. 1, a diagram of an exemplary mold for an ophthalmic lens is illustrated. As used herein, the terms "mold" and "mold assembly" refer to a form 100 having a cavity 105 into which a lens forming mixture can be dispensed such that upon reaction or cure of the lens forming mixture (not illustrated), an ophthalmic lens of a desired shape is produced. The molds and mold assemblies 100 of this invention are made up of more than one "mold parts" or "mold pieces" 101-102. The mold parts 101-102 can be brought together such that a cavity 105 is formed between the mold parts 101-102 in which a lens can be formed. This combination of mold parts 101-102 is preferably temporary. Upon formation of the lens, the mold parts 101-102 can again be separated for removal of the lens.

At least one mold part 101-102 has at least a portion of its surface 103-104 in contact with the lens forming mixture such that upon reaction or cure of the lens forming mixture that surface 103-104 provides a desired shape and form to the portion of the lens with which it is in contact. The same is true of at least one other mold part 101-102.

Thus, for example, in a preferred embodiment a mold assembly 100 is formed from two parts 101-102, a female concave piece (front piece) 102 and a male convex piece (back piece) 101 with a cavity formed between them. The portion of the concave surface 104 which makes contact with lens forming mixture has the curvature of the front curve of an ophthalmic lens to be produced in the mold assembly 100 and is sufficiently smooth and formed such that the surface of a ophthalmic lens formed by polymerization of the lens forming mixture which is in contact with the concave surface 104 is optically acceptable.

In some embodiments, the front mold piece 102 can also have an annular flange integral with and surrounding circular circumferential edge 108 and extends from it in a plane normal to the axis and extending from the flange (not shown).

The back mold piece 101 has a central curved section with a concave surface 106, convex surface 103 and circular circumferential edge 107, wherein the portion of the convex surface 103 in contact with the lens forming mixture has the curvature of the back curve of a ophthalmic lens to be produced in the mold assembly 100 and is sufficiently smooth and formed such that the surface of a ophthalmic lens formed by reaction or cure of the lens forming mixture in contact with the back surface 103 is optically acceptable. Accordingly, the inner concave surface 104 of the front mold half 102 defines the outer surface of the ophthalmic lens, while the outer convex surface 103 of the base mold half 101 defines the inner surface of the ophthalmic lens.

In some preferred embodiments, molds 100 can include two mold parts 101-102 as described above, wherein one or both of the front curve part 102 and the back curve part 101 of the mold 100 comprises a thermoplastic polyolefin compound with a DI water contact angle that is higher than the primary material in the compound.

Blended mold material resins can be obtained, for example, using different compounding methods, including hand blending, single screw compounding, twin screw and/or multiple screw compounding.

Preferred embodiments of a mold material include polyolefin; cyclic olefin; alicyclic polyolefin and cyclic olefin polymers (sometimes referred to as "COC"); including, in some embodiments polyolefins and COCs. Additives that may be compounded with the preferred mold materials include:

a) Siloxanes including a class of organosilicon compounds with empirical formula R_2SiO , where R is an organic group;

b) non-ionic surfactants such as: alkyl ethoxylates and glycerol monostearate; and

c) a polymer made from the monomer N-vinyl pyrrolidone, such as Polyvinylpyrrolidone.

Siloxanes can include $[SiO(CH_3)_2]_n$ (dimethylsiloxane) and $[SiO(C_6H_5)_2]_n$ (diphenylsiloxane), where n is typically > 4 . Siloxane organosilicon compounds can

include both organic and inorganic chemical compounds. Organic side chains can confer hydrophobic properties and an -Si-O-Si-O- backbone is inorganic.

Glycerol monostearate can include a lipophilic non-ionic surfactant with HLB of 3.6 - 4.2 and a chemical formula of $\text{CH}_3(\text{CH}_2)_{16}\text{COOCH}_2\text{CHOHCH}_2\text{OH}$.

- 5 Polyvinylpyrrolidone can include a nonionic powder with the chemical formula $(\text{C}_6\text{H}_9\text{NO})_x$.

Specific examples of additives that decrease the surface energy of a mold material predominantly made up of one or more of: polyolefin; cyclic olefins; and cyclic olefin copolymers; include:

- 10 1. a linear polydimethyl silicone, a suitable one is sold by Dow Corning under the designation MB50-001 SILICONE MASTERBATCH or Silixone® MB50-001; and
2. Alkyl Ethoxylates a suitable one is sold as Trilwet A® from Trillium Specialties LLC .

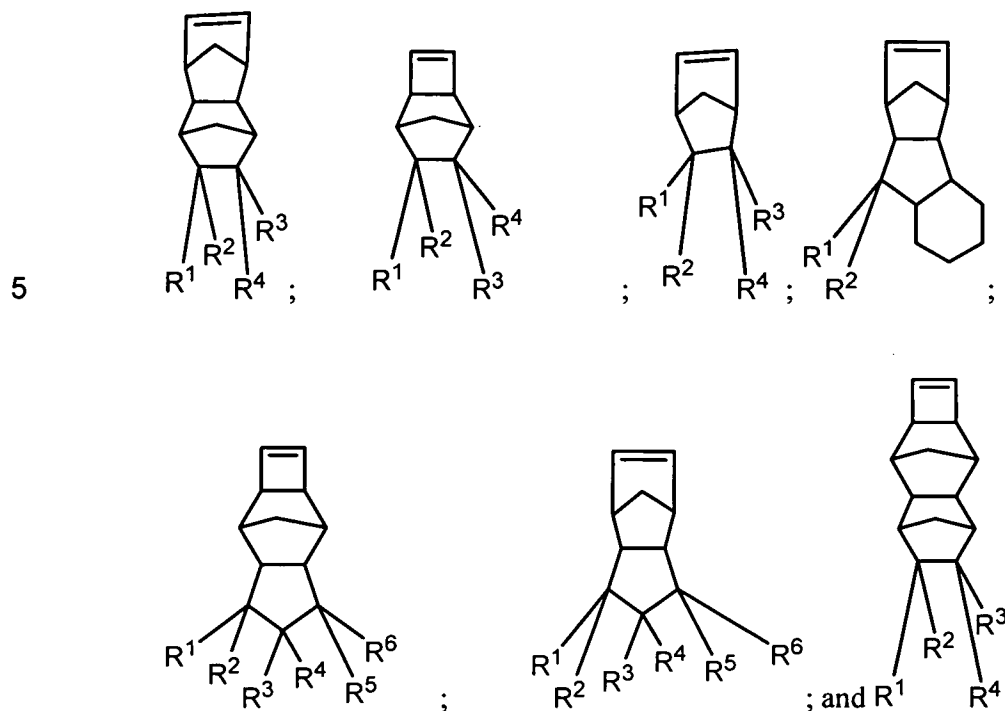
- 15 Preferred embodiments can also include a polyolefin of one or more of: polypropylene, polystyrene, polyethylene, polymethyl methacrylate, and modified polyolefins.

Thermoplastics that can be compounded with an additive can include, for example, one or more of: polypropylene, polystyrene and alicyclic polymers.

- 20 In some embodiments the thermoplastic resin can include an alicyclic polymer which refers to compounds having at least one saturated carbocyclic ring therein. The saturated carbocyclic rings may be substituted with one or more members of the group consisting of hydrogen, C_{1-10} alkyl, halogen, hydroxyl, C_{1-10} alkoxycarbonyl, C_{1-10} alkoxy, cyano, amido, imido, silyl, and substituted C_{1-10} alkyl where the
- 25 substituents are selected from one or more members of the group consisting of halogen, hydroxyl, C_{1-10} alkoxycarbonyl, C_{1-10} alkoxy, cyano, amido, imido, and silyl. Examples of alicyclic polymers include but are not limited to polymerizable cyclobutanes, cyclopentanes, cyclohexanes, cycloheptanes, cyclooctanes, biscyclobutanes, biscyclopentanes, biscyclohexanes, biscycloheptanes, biscyclooctanes, and
- 30 norbornanes. It is preferred that the at least two alicyclic polymers be polymerized by ring opening metathesis followed by hydrogenation. Since co-polymers are costly, it is preferable that the molds made from these co-polymers may be used several times to

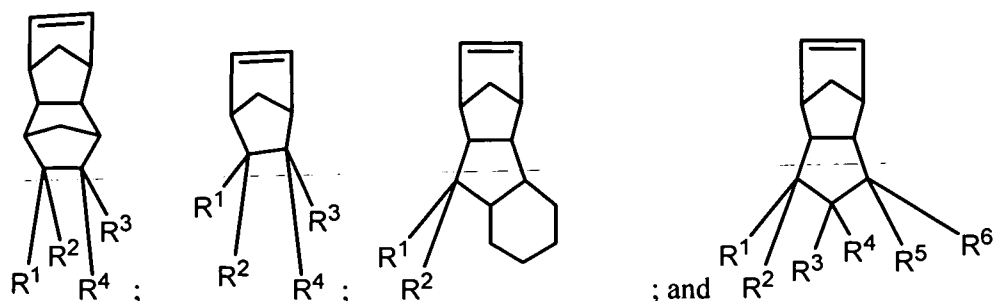
prepare lenses instead of once which is typical. For the preferred molds of the invention, they may be used more than once to produce lenses.

More particularly, examples of alicyclic polymer containing saturated carbocyclic rings include but are not limited to the following structures

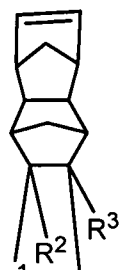


wherein R^{1-6} are independently selected from one or more members of the group consisting of hydrogen, C_{1-10} alkyl, halogen, hydroxyl, C_{1-10} alkoxycarbonyl, C_{1-10} alkoxy, cyano, amido, imido, silyl, and substituted C_{1-10} alkyl where the substituents selected from one or more members of the group consisting of halogen, hydroxyl, C_{1-10} alkoxycarbonyl, C_{1-10} alkoxy, cyano, amido, imido and silyl. Further two or more of R^{1-6} may be taken together to form an unsaturated bond, a carbocyclic ring, a carbocyclic ring containing one or more unsaturated bonds, or an aromatic ring. The preferred R^{1-6} is selected from the group consisting of C_{1-10} alkyl and substituted C_{1-10} alkyl where the substituents are selected from the group consisting of halogen, hydroxyl, C_{1-10} alkoxycarbonyl, C_{1-10} alkoxy, cyano, amido, imido and silyl.

The alicyclic co-polymers consist of at least two different alicyclic polymers. The preferred alicyclic co-polymers contain two or three different alicyclic polymers, selected from the group consisting of



The particularly preferred alicyclic co-polymer contains two different alicyclic monomers where the generic structure of the saturated carbocyclic rings of the alicyclic



polymers are of the formula R^1 R^4 and R^1 - R^4 are C_{1-10} alkyl.

- 5 A preferred alicyclic polymer contains two different alicyclic polymers and is sold by Zeon Chemicals L.P. under the trade name ZEONOR. There are several different grades of ZEONOR. Various grades may have glass transition temperatures ranging from 100°C to 160°C. A specifically preferred material is ZEONOR 1060R.

- Other mold materials that may combined with one or more additives to form an ophthalmic lens mold include, for example, Ziegler-Natta polypropylene resins (sometimes referred to as znPP). On exemplary Ziegler-Natta polypropylene resin is available under the name PP 9544 MED. PP 9544 MED is a clarified random copolymer for clean molding as per FDA regulation 21 CFR (c)3.2 made available by ExxonMobile Chemical Company. PP 9544 MED is a random copolymer (znPP) with ethylene group (hereinafter 9544 MED). Other exemplary Ziegler-Natta polypropylene resins include: Atofina Polypropylene 3761 and Atofina Polypropylene 3620WZ.
- 10
15

- Still further, in some embodiments, the molds of the invention may contain polymers such as polypropylene, polyethylene, polystyrene, polymethyl methacrylate, modified polyolefins containing an alicyclic moiety in the main chain and cyclic polyolefins. This blend can be used on either or both mold halves, where it is preferred that this blend is used on the back curve and the front curve consists of the alicyclic co-polymers.
- 20

In some preferred methods of making molds 100 according to the present invention, injection molding is utilized according to known techniques, however, embodiments can also include molds fashioned by other techniques including, for example: lathing, diamond turning, or laser cutting.

5 Typically, lenses are formed on at least one surface of both mold parts 101-102. However, if need be one surface of the lenses may be formed from a mold part 101-102 and the other lens surface can be formed using a lathing method, or other methods.

As used herein "lens forming surface" means a surface 103-104 that is used to mold a lens. In some embodiments, any such surface 103-104 can have an optical
10 quality surface finish, which indicates that it is sufficiently smooth and formed so that a lens surface fashioned by the polymerization of a lens forming material in contact with the molding surface is optically acceptable. Further, in some embodiments, the lens forming surface 103-104 can have a geometry that is necessary to impart to the lens surface the desired optical characteristics, including without limitation, spherical,
15 aspherical and cylinder power, wave front aberration correction, corneal topography correction and the like as well as any combinations thereof.

Methods

The following method steps are provided as examples of processes that may be implemented according to some aspects of the present invention. It should be
20 understood that the order in which the method steps are presented is not meant to be limiting and other orders may be used to implement the invention. In addition, not all of the steps are required to implement the present invention and additional steps may be included in various embodiments of the present invention.

Referring now to Fig. 2, a flowchart illustrates exemplary steps that may be
25 used to implement the present invention. At 201, a first TPR compounded with a second TPR to increase water contact angle or a TPR with an additive to increase water contact angle, is plasticized and prepared for use in an injection molding process. Injection molding techniques are well known and preparation typically involves heating resin pellets beyond a melting point.

30 At 202, the plasticized resin is injected into an injection mold shaped in a fashion suitable for creating an ophthalmic lens mold part 101-102. At 203, the injection mold is typically placed in a pack and hold status for an appropriate amount of

time, which can depend, for example upon the resin utilized and the shape and size of the mold part. At 204, the formed mold part 101-102 is allowed to cool and at 205, the mold part 101-102 can be ejected, or otherwise removed from the injection mold.

Referring now to Fig. 3, some embodiments of the present invention include

5 methods of making an ophthalmic lens comprising, consisting essentially of, or consisting of the following steps. At 301 one or more mold parts 101-102 are created which comprise, consist essentially of, or consist of, including a TPR compounded with an additive for reducing the surface energy of the TPE. At 302, an uncured lens

10 formulation is dispensed onto the one or more mold parts 101-102 and at 303, the lens formulation is cured under suitable conditions. Additional steps can include, for example, hydrating a cured lens until it releases from a mold part 101-102 and leaching acute ocular discomfort agents from the lens.

As used herein, the term “uncured” refers to the physical state of a lens formulation prior to final curing of the lens formulation to make the lens. In some

15 embodiments, lens formulations can contain mixtures of monomers which are cured only once. Other embodiments can include partially cured lens formulations that contain monomers, partially cured monomers, macromers and other components.

As used herein, the phrase “curing under suitable conditions” refers to any suitable method of curing lens formulations, such as using light, heat, and the

20 appropriate catalysts to produce a cured lens. Light can include, in some specific examples, ultra violet light. Curing can include any exposure of the lens forming mixture to an actinic radiation sufficient to cause the lens forming mixture to polymerize.

Examples

25 The following non-limiting examples illustrate demonstrate some embodiments of the present invention. Table 1 lists two TPRs, a polypropylene PP9544 MED and Zeonor 1060, as described above, and associated DI water contact angles. The PP9544 MED had a DI water contact angle of about 103.9° and the Zeonor 1060 had a contact angle of about 96.3°. Each of the PP9544 MED and Zeonor 1060 are also shown with

30 various additives, or compounded together, and an associated DI water contact angle.

Typically, it would be expected that a compound of two TPRs would have a DI water contact angle with a value somewhere between the DI water contact angle of each of the component TPRs, generally in line with a ration of the two TPRs.

Unexpectedly, it was discovered a combination of the PP9544 MED and the Zeonor 1060 did not result in a DI water contact angle that fell between 103.9° (the contact angle of PP9544 MED) and 96.3° (the DI water contact angle of Zeonor 1060).

- Instead, a compound including PP9544 MED and Zeonor 1060 resulted in a DI water contact angle of. between about 104.4 and 107.1, depending upon the ratio of the compounded materials. Surprisingly, the DI water contact angles for each of the compounds was greater than the DI water contact angle of either of the constituents of the compound. a contact angle greater than e

Table 1	
Mold Material	Avg. DI Water Contact Angle by PGX (n=8-24)
PP9544	103.9 +/- 1.8
95% w.t. PP9544 + 5% w.t. MB50-001	107.1 +/- 2.8
55% w.t. Zeonor + 45% w.t. PP9544	104.4 +/- 1.1
75% w.t. Zeonor + 25% w.t. PP9544	106.0 +/- 0.8
95% w.t.(55% Zeonor/45% PP9544) + 5% w.t. MB50-001	108.3 +/- 2.1
Zeonor 1060R	96.3 +/- 3.6
97.5% w.t. Zeonor + 2.5% w.t. MB50-001	108.5 +/- 0.6
95% w.t. Zeonor + 5% w.t. MB50-001	111.1 +/- 1.2
90% w.t. Zeonor + 10% w.t. MB50-001	106.6 +/- 3.2
Zeonor 1060R + 1% w.t. PVP	102.3 +/- 3.4
Zeonor 1060R + 2.5% w.t. PVP	102.8 +/- 4.1

- Referring now to Fig. 4, a boxplot graph 400 is provided which illustrates contact angle characteristics of mold materials. The listed mold materials 402 include homogeneous mold materials 408, compounded mold materials 403-404 and materials with additives 405-407. The compounded mold materials 403-405 correlate with an increased DI water contact angle as compared to either of the component TPRs comprising the compound, and also correlate with relatively fast release times of a lens from a respective mold parts.

Mold parts formed from a TPR with an additive to reduce a respective DI water contact angle also indicate relatively faster lens release times. It is interesting to note

that the mold parts formed from Zeonor 1060R with an additive (5% MB50-001) resulted in a relatively high DI water contact angle of about 111.1°. In addition, as compared to homogeneous Zeonor 1060R, and the corresponding release times for the Zeonor 1060R with an additive (5% MB50-001) 406 were faster than the homogeneous Zeonor 1060R 407. However, the data indicates that unexpectedly, there is not a direct relationship between DI water contact angle of a mold material and release times of a lens from the mold, if other characteristics, such as the mold material also change. Accordingly, for example a compound of polypropylene and Zeonor 1060R may have a faster release time 403-405 than a release time 407 of Zeonor 1060R with an additive of 5% MB50-01, even though the Zeonor 1060R with the MB50-001 has a higher DI water contact angle than the compound of polypropylene and Zeonor 1060. Notwithstanding this phenomenon, the data does support the present invention by indicating that a release time of a homogeneous TPR mold material, such as Zeonor 1060R, can be made faster by increasing the DI water contact angle via a compound or additive.

Table 2 below also indicates that the incidence of a no lens inspection (after aqueous hydration) is also decreased when a TPR mold material is compounded with a mold material to increase the DI water contact angle or an additive to increase the DI water contact angle. A no lens inspection, includes ascertaining whether a lens has released from a mold part in which it was formed. Table 2 illustrates that when a TPR, such as PP9544 and Zeonor 1060R is compounded with another TPR to increase the DI water contact angle the incidence of no lens occurrences (after aqueous hydration) decreases. Similarly, when either PP9544 or Zeonor 1060R is combined with an additive to increase the DI water contact angle, the incidence of no lens (after aqueous hydration) occurrences decreases.

Table 2	
Mold Material	No Lens Ranges (%)
PP9544	~30 to 58
95% w.t. PP9544 + 5% w.t. MB50-001	~0 to 10
55% w.t. Zeonor + 45% w.t. PP9544	~0 to 16
75% w.t. Zeonor + 25% w.t. PP9544	~18

95% w.t. (55% Zeonor/45% PP9544) + 5% w.t. MB50-001	~0 to 10
Zeonor 1060R	~80 to 100
95% w.t. Zeonor + 5% w.t. MB50-001	~18
Zeonor 1060R + 2.5% w.t. PVP	102.8 +/- 4.1

Conclusion

The present invention, as described above and as further defined by the claims
5 below, provides mold parts 101-102 fashioned from a thermal plastic resin
compounded with another thermal plastic resin or with an additive to increase a DI
water contact angle of the plastic mold part, improve release performance of an
ophthalmic lens formed therein, and an ophthalmic lens formed in the mold part in
hydration, and particularly in aqueous hydration.

10

CLAIMS

What is claimed is:

- 5 1. An improved method of molding an ophthalmic lens, wherein a lens forming mixture is cured in a cavity of a desired shape formed by two or more mold parts;
- the improvement comprising curing the lens forming mixture in a cavity formed with at least one mold part comprising a first thermal plastic resin compounded with a
- 10 second thermal plastic resin resulting in a thermal plastic compound with a deionized water contact angle that is greater than the deionized water contact angle of either the first thermal plastic resin or the second thermal plastic resin.
- 15 2. The method of claim 1, wherein a first mold part comprises a concave surface, a second mold part comprises a convex surface, and at least the second mold part comprises the thermal plastic compound with a deionized water contact angle that is greater than the deionized water contact angle of either the first thermal plastic resin or the second thermal plastic resin.
- 20 3. The method of claim 1, wherein the at least one mold part comprising a first thermal plastic resin compounded with a second thermal plastic resin resulting in a thermal plastic compound with a deionized water contact angle that is greater than the
- 25 deionized water contact angle of either the first thermal plastic resin or the second thermal plastic resin, additionally comprises an additive that increases the deionized water contact angle of the at least one mold part.
- 30 4. The method of claim 3 wherein at least one of the mold parts is transparent to polymerization initiating radiation and the cavity comprises the shape and size of an ophthalmic lens, the method additionally comprising the steps of:

depositing lens forming mixture comprising a polymerizable composition in the cavity;

exposing the mold parts and the polymerizable composition to polymerization-initiating radiation to form an ophthalmic lens; and

5 exposing the ophthalmic lens to an aqueous hydration solution until the ophthalmic lens is released from one of the mold parts.

10 5. The method of claim 4 additionally comprising the step of:
decreasing the time in which the ophthalmic lens is exposed to the aqueous hydration solution until the ophthalmic lens is released.

15 6. The method of claim 4, wherein the deionized water contact angle of a mold part comprising the first thermal plastic resin without the second thermal plastic resin is less than 100° and increases to greater than 101° when compounded with the second thermal plastic resin.

20 7. The method of claim 4 wherein the additive comprises a linear polydimethyl silicone.

25 8. The method of claim 4 wherein the additive comprises alkyl ethoxylates.

9. An improved method of molding an ophthalmic lens, wherein a lens forming mixture is cured in a cavity of a desired shape formed by two or more mold parts;

30 the improvement comprising curing the lens forming mixture in a cavity formed with at least one mold part comprising a first thermal plastic resin with an additive, wherein the addition of the additive results in a thermal plastic compound with a

deionized water contact angle that is greater than the deionized water contact angle of either the thermal plastic resin without the additive.

5 10. The method of claim 9 wherein the additive comprises a linear polydimethyl silicone.

10 11. The method of claim 9 wherein the additive comprises alkyl ethoxylates.

12 12 A mold assembly for forming an ophthalmic lens, the mold assembly comprising:
 a first mold part and a second mold part positioned relative to each other
15 to form a cavity in a shape and size suitable to form an ophthalmic lens;
 at least one of the first mold part and the second mold part comprising a lens forming surface; and
 wherein at least one of the first mold part and the second mold part
20 comprises a first thermal plastic resin compounded with a second thermal plastic resin resulting in a thermal plastic compound with a deionized water contact angle that is greater than the deionized water contact angle of either the first thermal plastic resin or the second thermal plastic resin.

25 13. The mold of claim 12 wherein at least one of the first thermoplastic resin and the second plastic resin comprises polypropylene.

30 14. The mold of claim 12 wherein at least one of the first thermoplastic resin and the second plastic resin comprises a cyclic olefin polymer or cyclic olefin co-polymer.

15. The mold of claim 12 wherein the at least one of the first mold part and the second mold part comprising a first thermal plastic resin compounded with a second thermal plastic resin comprises about 55% wt cyclic olefin polymer and 45% wt ziegler natta polypropylene.

5

16. The mold of claim 12 wherein the at least one of the first mold part and the second mold part comprising a first thermal plastic resin compounded with a second thermal plastic resin comprises about 75% wt cyclic olefin polymer and 25% wt ziegler natta polypropylene.

10

17. The mold of claim 12 wherein the first thermal plastic resin compounded with a second thermal plastic resin comprises a melt flow rate less than about 21g/10 minutes.

15

18. An ophthalmic lens produced by a method comprising the steps of:
dispensing an uncured lens formulation into a first mold part;
positioning a second mold part relative to the first mold part to form a cavity containing the lens formulation in a shape and size suitable to form an ophthalmic lens;

20

wherein at least one of the first mold part and the second mold part comprises a first thermal plastic resin compounded with a second thermal plastic resin resulting in a thermal plastic compound with a deionized water contact angle that is greater than the deionized water contact angle of either the first thermal plastic resin or the second thermal plastic resin; and

25

curing said lens formulation under actinic conditions suitable to the uncured lens formulation.

30

19. The ophthalmic lens of claim 18 wherein the uncured lens formulation comprises a silicone hydrogel formulation.

20. The lens of claim 18 wherein the uncured lens formulation comprises at least one of: etafilcon A, genfilcon A, lenefilcon A, narafilcon A, polymacon and galyfilcon A, and senofilcon A.

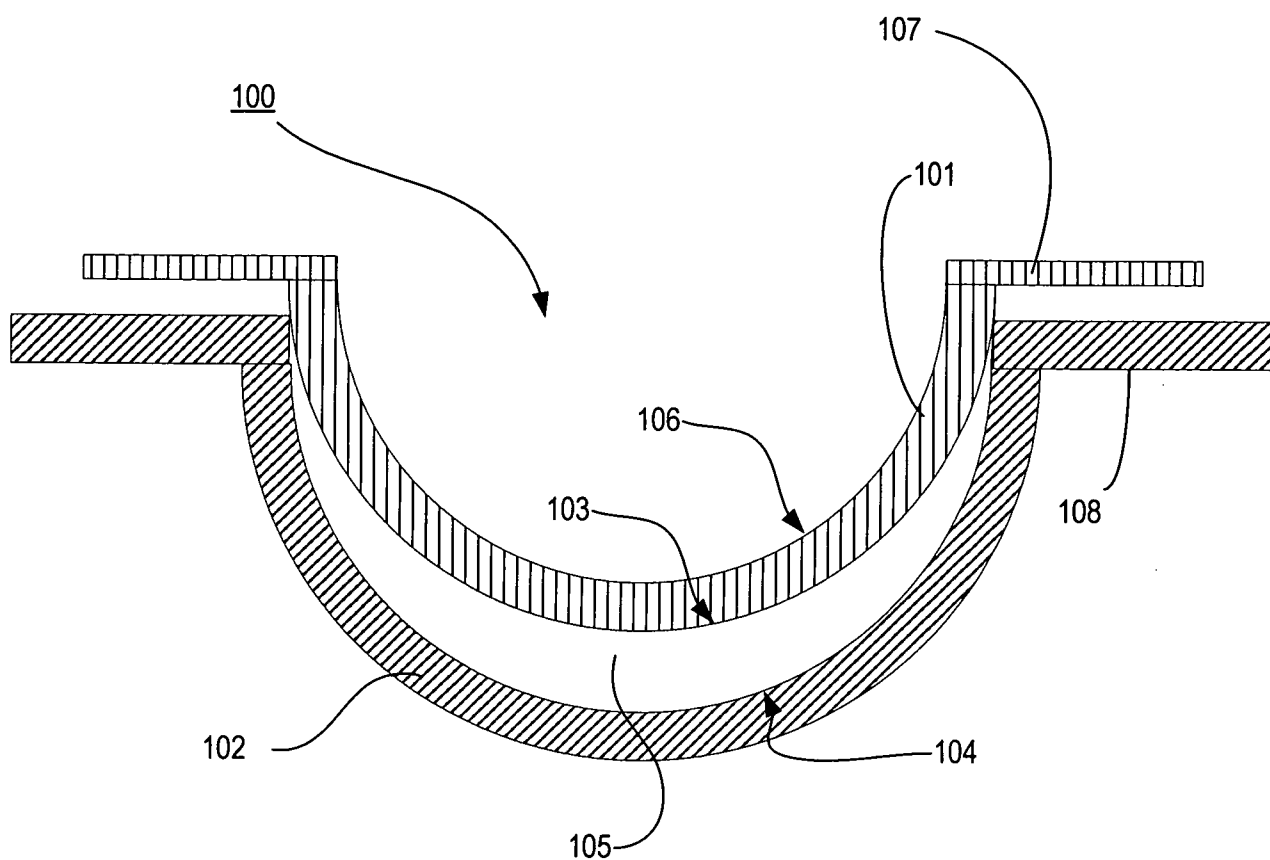


FIG. 1

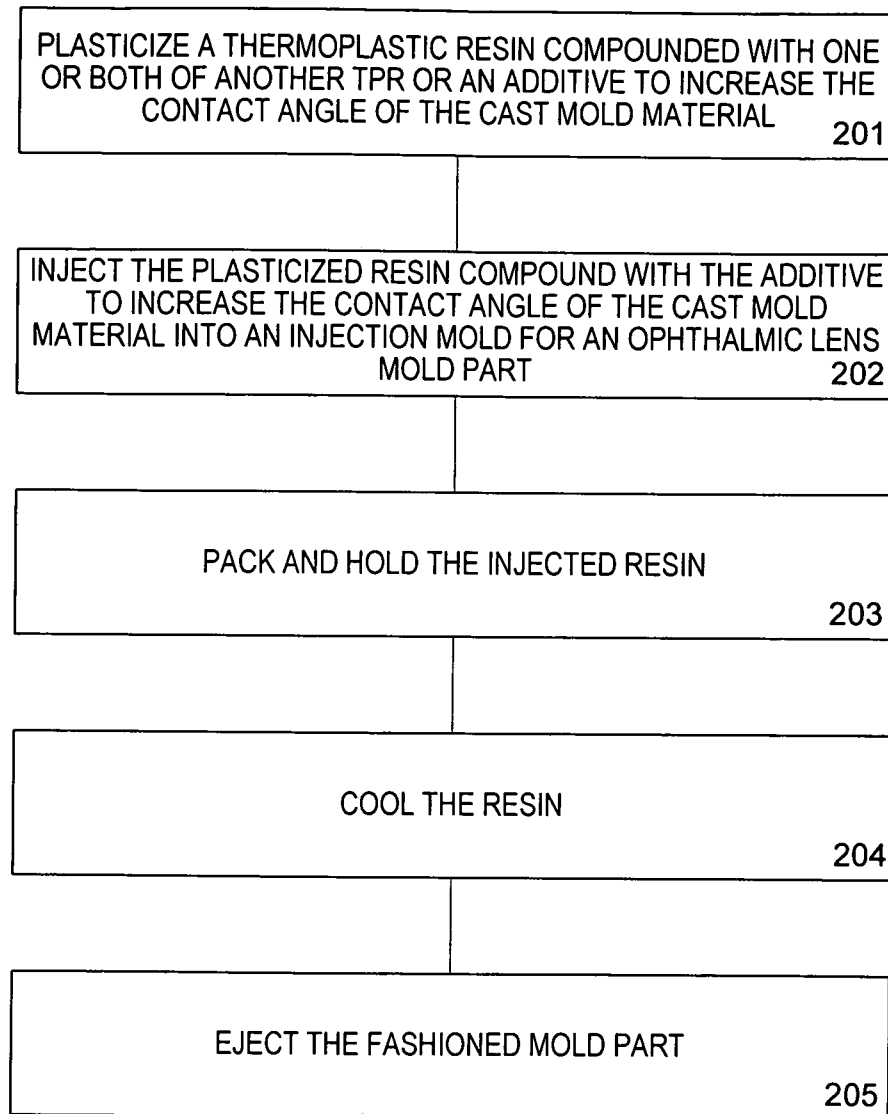


FIG. 2

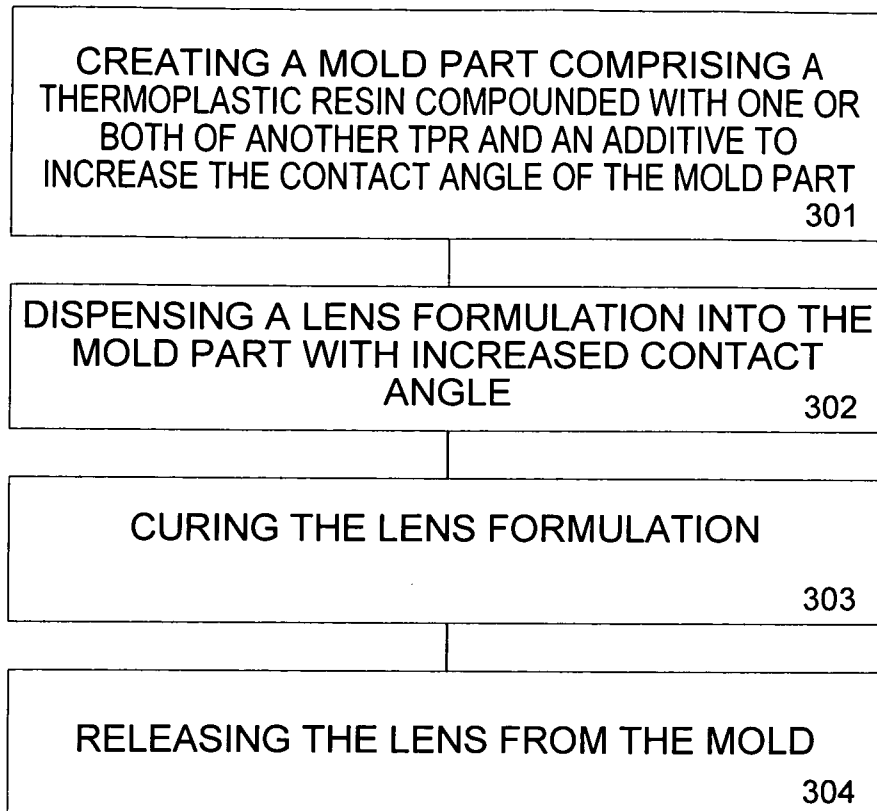


FIG. 3

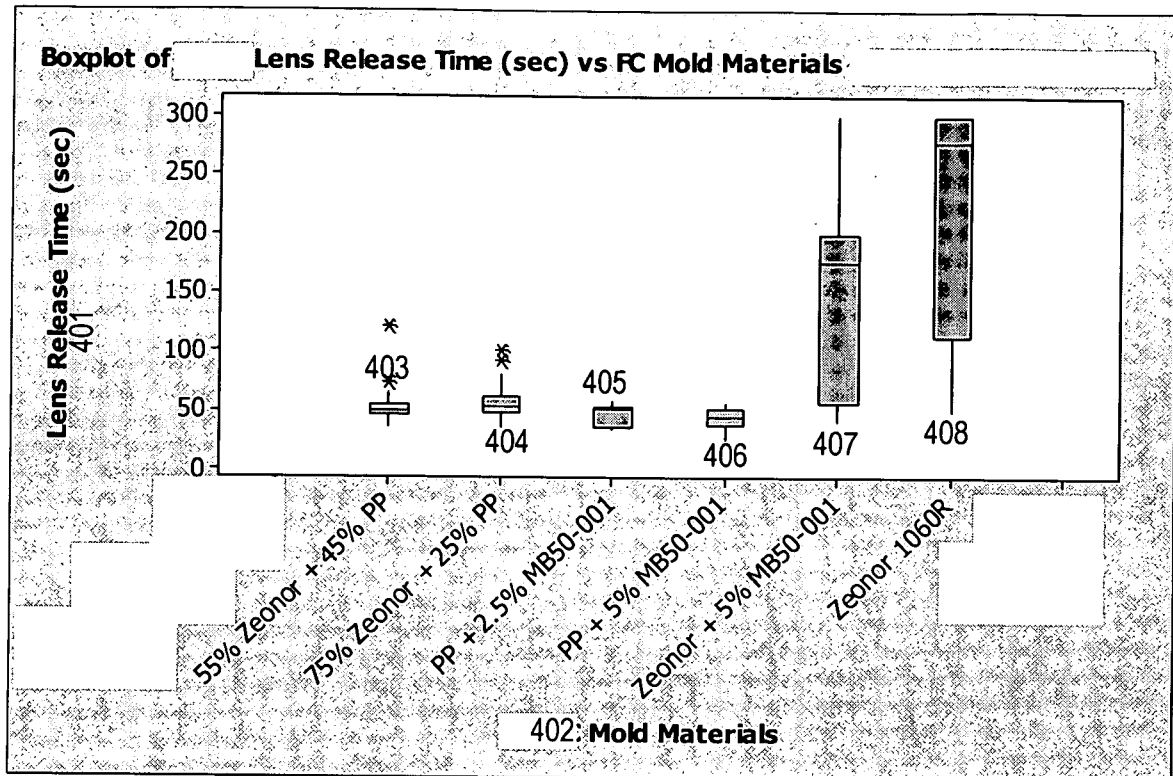
400

FIG. 4

INTERNATIONAL SEARCH REPORT

International application No

PCT/US2008/012649

A. CLASSIFICATION OF SUBJECT MATTER

INV. B29D11/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

B29D

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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☐ Further documents are listed in the continuation of Box C.☒ See patent family annex.

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G document member of the same patent family

Date of the actual completion of the international search

13 February 2009

Date of mailing of the international search report

25/02/2009

Name and mailing address of the ISA/

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

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