



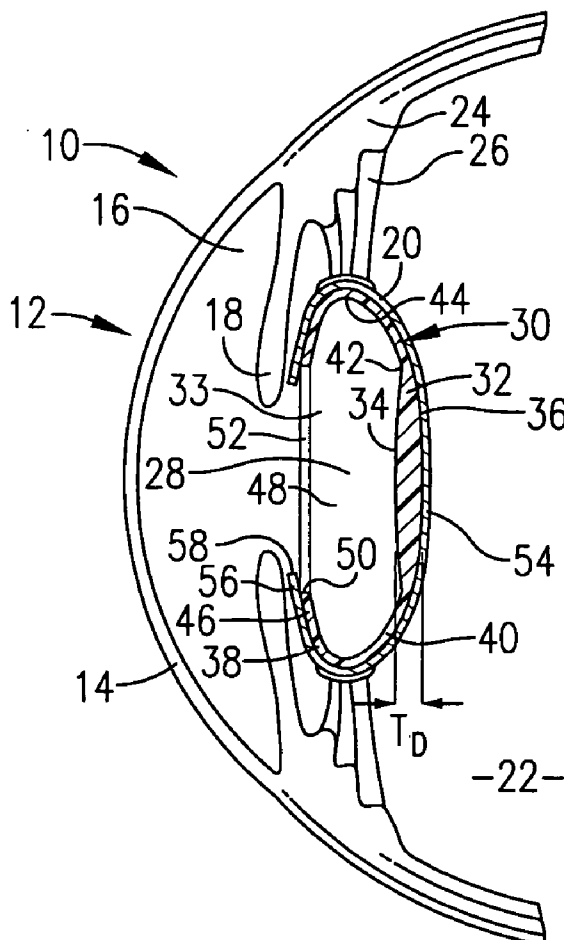
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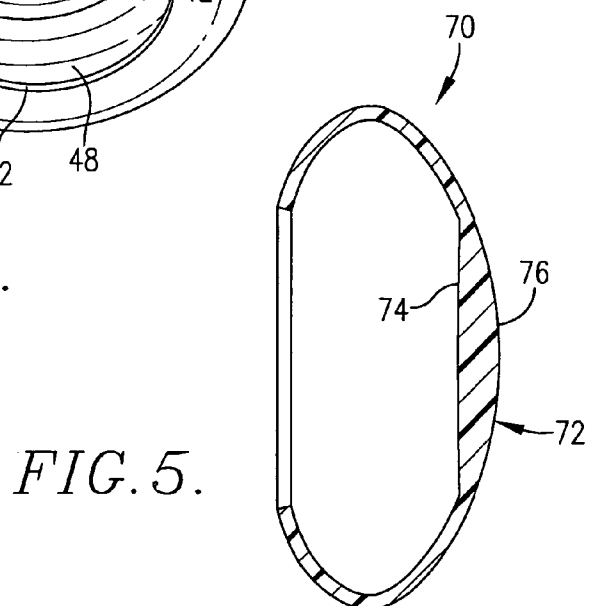
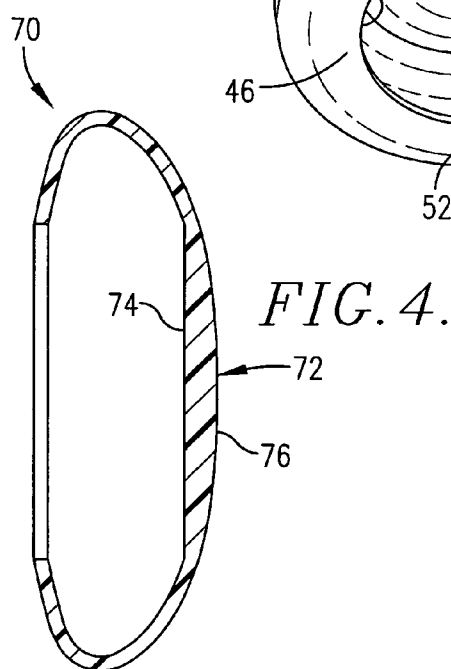
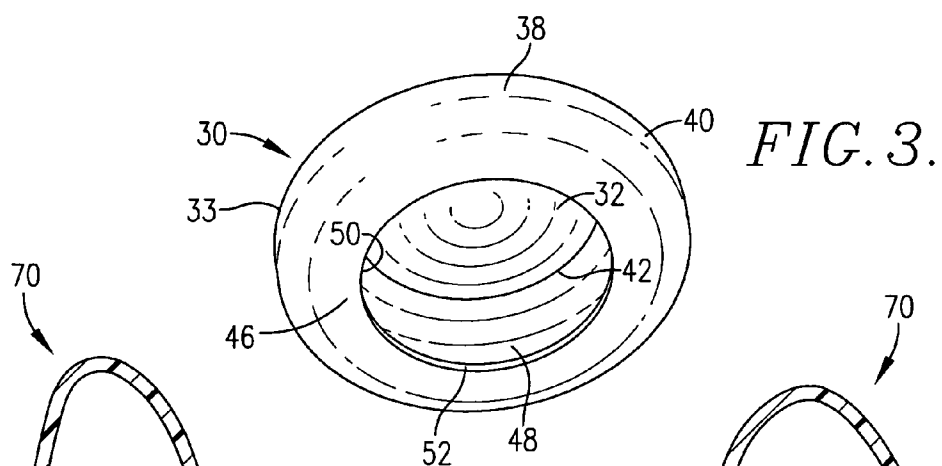
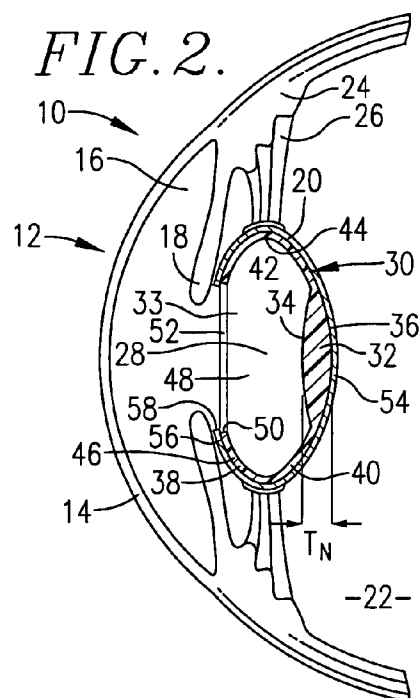
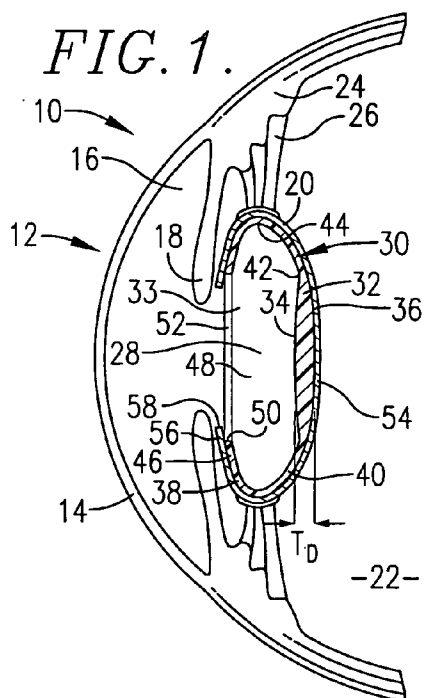
(19) **United States**(12) **Patent Application Publication**
Woods(10) **Pub. No.: US 2005/0131535 A1**(43) **Pub. Date: Jun. 16, 2005**(54) **INTRAOCULAR LENS IMPLANT HAVING
POSTERIOR BENDABLE OPTIC**(52) **U.S. Cl. 623/6.37; 623/6.22**(76) **Inventor: Randall Woods, Gilbert, AZ (US)**(57) **ABSTRACT**

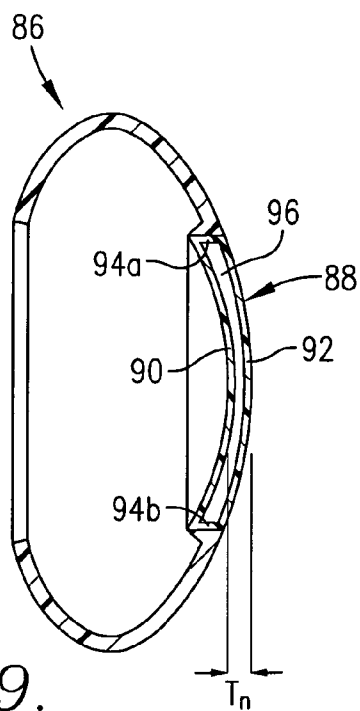
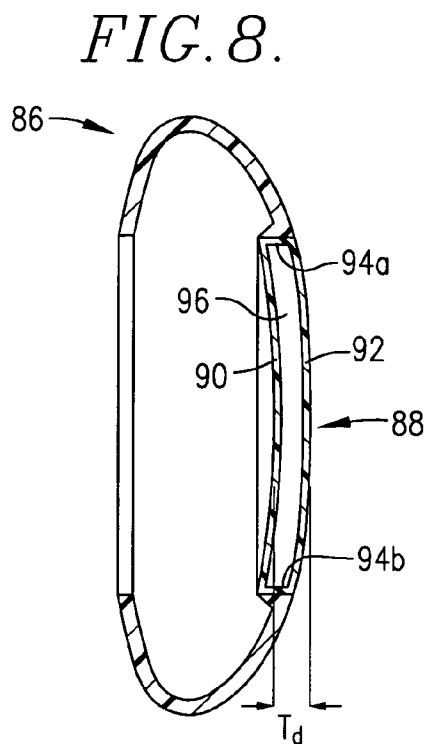
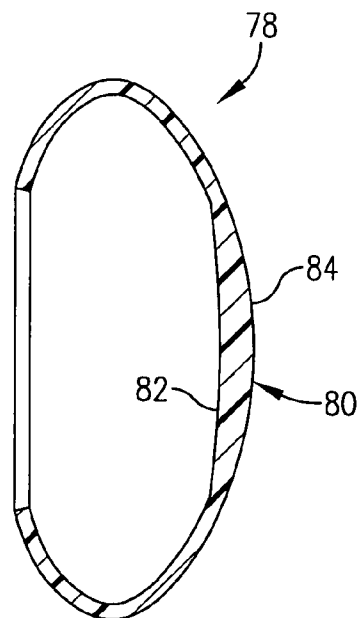
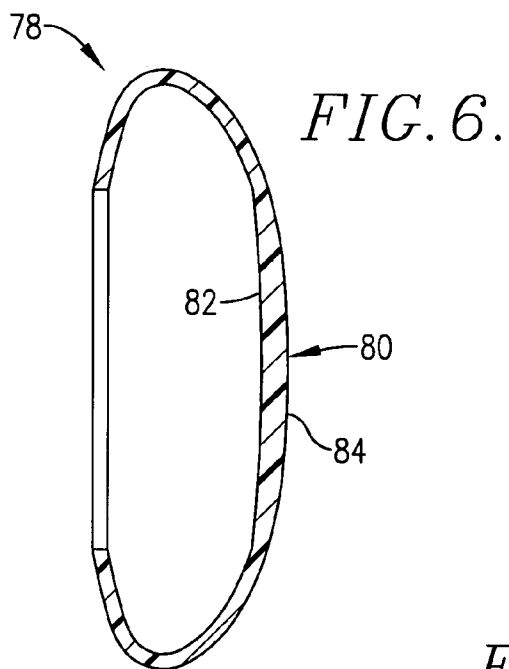
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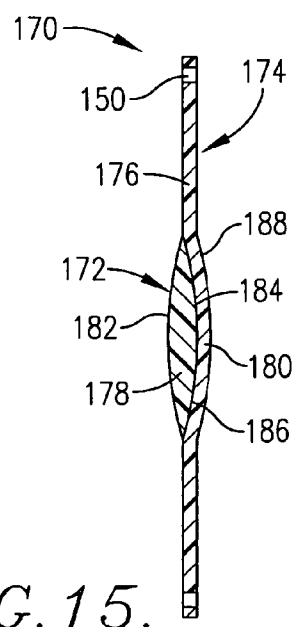
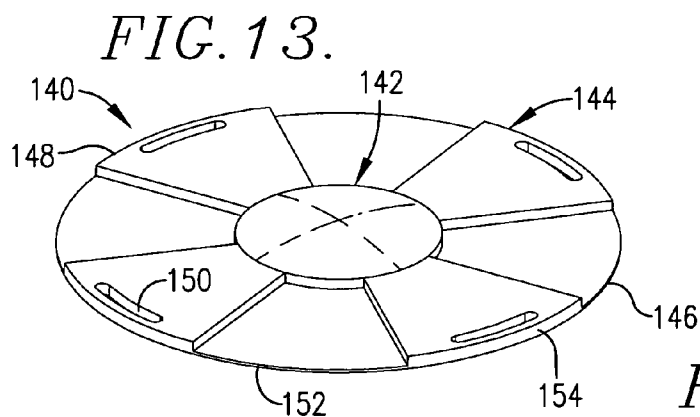
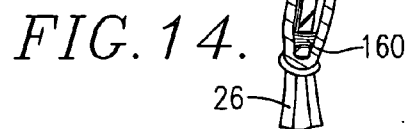
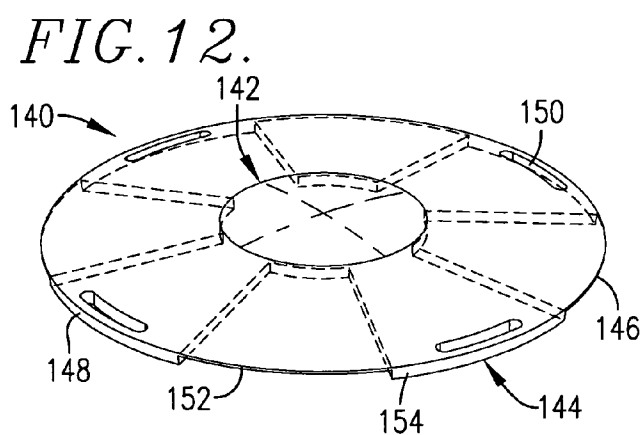
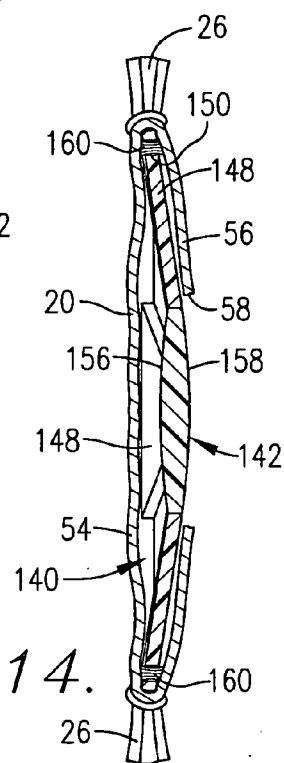
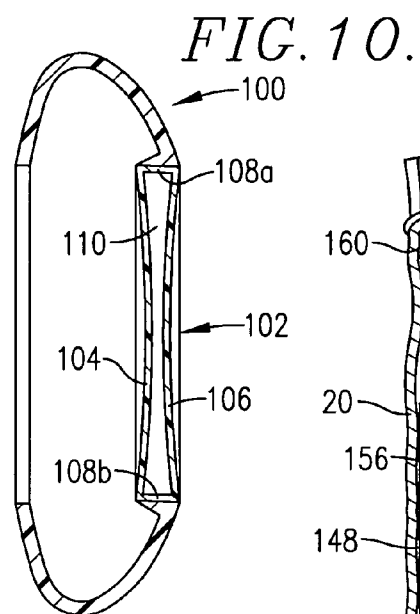
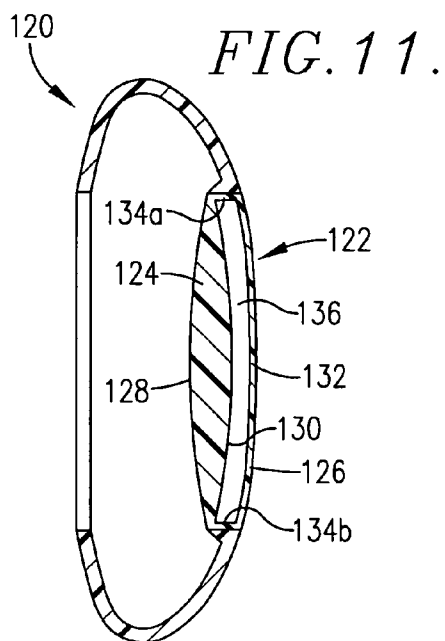
(21) **Appl. No.: 10/736,431**(22) **Filed: Dec. 15, 2003****Publication Classification**(51) **Int. Cl.⁷ A61F 2/16**

An intraocular lens (30) having focusing capabilities permitting focusing movement of the lens (30) in response to normal ciliary body (24) movement incident to changes in the distance between the eye and an object under observation is provided. The lens (30) is designed for surgical implantation within the capsule (20) of an eye (10) and includes an optic (32) and an optic positioning element (33) which cooperate to form the lens (30). Accommodation is achieved by relying upon the thickening and thinning of the optic (32) as a result of the normal retracting and contracting of the ciliary body (24) in response to the distance of an object from the viewer.









INTRAOCULAR LENS IMPLANT HAVING POSTERIOR BENDABLE OPTIC

BACKGROUND OF THE INVENTION

[0001] 1. Field of the Invention

[0002] The present invention relates to accommodating intraocular lenses which can be surgically implanted as a replacement for the natural crystalline lens in the eyes of cataract patients.

[0003] 2. Description of the Prior Art

[0004] Cataracts occur when the crystalline lens of the eye becomes opaque. The cataracts may be in both eyes and, being a progressive condition, may cause fading vision and eventual blindness. Cataracts were once surgically removed along with the anterior wall of the capsule of the eye. The patient then wore eyeglasses or contact lenses which restored vision but did not permit accommodation and gave only limited depth perception.

[0005] The first implant of a replacement lens within the eye occurred in 1949 and attempted to locate the replacement lens in the posterior chamber of the eye behind the iris. Problems such as dislocation after implantation forced abandonment of this approach, and for some period thereafter intraocular lenses were implanted in the anterior chamber of the eye.

[0006] Others returned to the practice of inserting the lens in the area of the eye posterior to the iris, known as the posterior chamber. This is the area where the patient's natural crystalline lens is located. When the intraocular lens is located in this natural location, substantially normal vision may be restored to the patient and the problems of forward displacement of vitreous humor and retina detachment encountered in anterior chamber intraocular lenses are less likely to occur. Lenses implanted in the posterior chamber are disclosed in U.S. Pat. Nos. 3,718,870, 3,866,249, 3,913,148, 3,925,825, 4,014,049, 4,041,552, 4,053,953, and 4,285,072. None of these lenses has focusing capability.

[0007] Lenses capable of focusing offer the wearer the closest possible substitute to the crystalline lens. U.S. Pat. No. 4,254,509 to Tennant discloses a lens which moves in an anterior direction upon contraction of the ciliary body, and which is located anterior to the iris. Though providing focusing capabilities, it presents the same disadvantages as other anterior chamber lenses.

[0008] U.S. Pat. No. 4,409,691 to Levy is asserted to provide a focusable intraocular lens positioned within the capsule. This lens is located in the posterior area of the capsule and is biased toward the fovea or rear of the eye. The '691 lens is deficient because it requires the ciliary muscle to exert force through the zonules on the capsule in order to compress the haptics inward and drive the optic forward for near vision. However, the ciliary muscles do not exert any force during contraction because the zonules, being flexible filaments, exert only tension, not compression on the capsule. The natural elasticity of the lens causes the capsule to become more spherical upon contraction of the ciliary muscle. Thus, there is no inward force exerted on the capsule to compress the haptics of the Levy lens, and therefore accommodate for near vision.

[0009] U.S. Pat. No. 5,674,282 to Cumming is directed towards an accommodating intraocular lens for implanting within the capsule of an eye. The Cumming lens comprises a central optic and two plate haptics which extend radially outward from diametrically opposite sides of the optic and are movable anteriorly and posteriorly relative to the optic. However, the Cumming lens suffers from the same shortcomings as the Levy lens in that the haptics are biased anteriorly by pressure from the ciliary bodies. This will eventually lead to pressure necrosis of the ciliary body.

[0010] There is a need for an intraocular lens implant capable of focusing in a manner similar to the natural lens. This lens implant should be readily insertable into the capsule and should last for a substantial number of years without damaging any of the eye components.

SUMMARY OF THE INVENTION

[0011] The present invention fills this need by providing an intraocular lens with focusing capabilities which is safe for long-term use in an eye.

[0012] In more detail, the lens of the invention comprises an optic coupled to an optic positioning element. The optic positioning element is preferably balloon-shaped or preferably comprises an outwardly extending disc (optionally with thicker, radially extending "winged" portions separated by thin membranes). The optic is resilient and can be formed of a solid material (e.g., silicone) or can be gas-filled.

[0013] As a result of the size and shape of the inventive lens and the material of which the optic is formed, the focusing action of the natural lens is simulated. That is, the ciliary body of the eye continues to exert a muscular force radially outward from the center of the capsule through the zonular fibers so as to alter the thickness of the optic, resulting in a decrease in light convergence as is necessary for viewing objects distant from the viewer. When viewing an object close to the viewer, the ciliary body contracts, thus releasing the outward pull on the zonular fibers. This alters the thickness of the optic to result in an increase in light convergence as is necessary for viewing nearby objects.

[0014] The optic can be one of many shapes as described in more detail below. Furthermore, the optic can be formed of a solid, liquid, or gel refractive material, or the optic can be gas-filled (e.g., air) so long as the chosen materials are safe for use in the eye. The shape of the optic and the material of which the optic is formed are dependent upon one another. That is, the shape is chosen based upon the refractive index of the material used to form the optic, and this choice is made to result in an optic which will highly converge light upon contraction of the ciliary body. Thus, if the refractive index of the optic material is greater than about 1.33 (the refractive index of the fluids within the eye), then optic shapes such as meniscus, planoconvex, and biconvex would converge light. On the other hand, if the refractive index of the optic material is less than about 1.33, then optic shapes such as biconcave and planoconcave would converge light.

BRIEF DESCRIPTION OF THE DRAWING FIGURES

[0015] FIG. 1 is a vertical sectional view showing placement of the lens of the invention within the capsule of an eye, with the eye focused on an object distant from the viewer;

[0016] FIG. 2 is a vertical sectional view showing the change in shape of the lens of FIG. 1 when focused on an object near the viewer;

[0017] FIG. 3 is a perspective view of the lens of FIGS. 1-2, shown in its resting state;

[0018] FIG. 4 is a vertical sectional view showing another embodiment of the inventive lens, with the lens being focused on an object distant from the viewer;

[0019] FIG. 5 is a vertical sectional view showing the change in shape of the lens of FIG. 4 when focused on an object near the viewer;

[0020] FIG. 6 is a vertical sectional view showing another embodiment of the inventive lens, with the lens being focused on an object distant from the viewer;

[0021] FIG. 7 is a vertical sectional view showing the change in shape of the lens of FIG. 6 when focused on an object near the viewer;

[0022] FIG. 8 is a vertical sectional view showing another embodiment of the inventive lens having a gas-filled optic, with the lens being focused on an object distant from the viewer;

[0023] FIG. 9 is a vertical sectional view showing the change in shape of the lens of FIG. 8 when focused on an object near the viewer;

[0024] FIG. 10 is a vertical sectional view showing another embodiment of the inventive lens where the lens has a gas-filled optic;

[0025] FIG. 11 is a vertical sectional view showing another inventive lens having a combination optic;

[0026] FIG. 12 is an upper perspective view of another lens according to the invention utilizing a resilient optic with a different type of optic positioning element;

[0027] FIG. 13 is a lower perspective view of the lens of FIG. 12;

[0028] FIG. 14 is a sectional view of the lens shown in FIGS. 12-13; and

[0029] FIG. 15 is a sectional view of another embodiment of the lens of FIG. 12, where the optic is a combination optic.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0030] Referring now to the drawings, the present invention is in the form of an intraocular lens for surgical replacement of the human lens in the treatment of cataracts in the human eye. FIG. 1 shows the various components of the human eye pertinent to this invention. Briefly, the eye 10 includes a frontal portion 12 and a rearward portion (not shown). The frontal portion 12 of the eye 10 is covered by a cornea 14 which encloses and forms an anterior chamber 16. The anterior chamber 16 contains aqueous fluid and is bounded at the rear by an iris 18. The iris 18 opens and closes to admit appropriate quantities of light into the inner portions of the eye 10. The eye 10 includes a capsule 20 which ordinarily contains the natural crystalline lens. When the eye 10 focuses, the capsule 20 changes shape to appro-

priately distribute the light admitted through the cornea 14 and the iris 18 to the retina (not shown) at the rearward portion of the eye 10.

[0031] Although not shown in the accompanying figures, the retina is composed of rods and cones which act as light receptors. The retina includes a fovea which is a rodless portion which provides for acute vision. The outside of the rearward or posterior portion of the eye 10 is known as the sclera. The sclera joins with, and forms a portion of, the covering for the optic nerve. Images received by the retina are transmitted through the optic nerve to the brain. The area between the retina and the capsule 20 is occupied by vitreous fluid. Finally, the eye 10 includes a ciliary muscle or body 24 having zonular fibers 26 (also referred to as zonules) which are attached to the capsule 20.

[0032] Ocular adjustments for sharp focusing of objects viewed at different distances is accomplished by the action of the ciliary body 24 on the capsule 20 and crystalline lens (which would be located at numeral 28 in the natural, unmodified eye) through the zonular fibers 26. The ciliary body 24 contracts, allowing the capsule 20 to return to a more spherical shape for viewing objects that are nearer the viewer. When the ciliary body 24 retracts and pulls on the zonular fibers 26 to make the capsule 20 more discoid, objects at a distance can be viewed in proper focus.

1. Lens Embodiment of FIGS. 1-3

[0033] Referring to FIGS. 1-3, the inventive lens is an accommodating lens 30 which includes a biconvex optic 32 and an optic positioning element 33. The optic 32 comprises a convex anterior surface 34 and a convex posterior surface 36. The optic positioning element 33 comprises a resilient body 38. Resilient body 38 comprises an outer wall 40 which extends radially from optic 32. Resilient body 38 is preferably integral and essentially flush with optic 32 at optic perimeter 42 where wall 40 joins optic 32. Wall 40 then curves to form a bight 44 and converges on the posterior side 46 of lens 30. Wall 40 forms a chamber 48 and terminates at location 50 to form an opening 52 which communicates with the chamber 48, allowing fluids to enter and fill the chamber 48.

[0034] Preferably, the overall shape of lens 30 in its original resting, non-deformed shape generally conforms to the shape of capsule 20 when capsule 20 is focused to view an object near the viewer (FIGS. 1 and 3). Thus, outer wall 40 of the resilient body 38 cooperates with optic 32 to form a lens having an overall discoid or saucer-like shape as best shown in FIG. 1. The lens 30 is of sufficient size that optic 32 mildly urges against the posterior wall 54 of the capsule 20, while the posterior side 46 of lens 30 urges against the anterior wall 56 of the capsule 20. The optic 30 is formed of a resilient, bendable material which allows for changes in thickness of optic 30.

[0035] Intraocular lens 30 substitutes both locationally and functionally for the original, natural, crystalline lens (which would normally be at location 28). To insert the lens 30 into the capsule 20, an ophthalmic surgeon would remove the natural lens (and thus the cataracts) by conventional methods, leaving an opening 58 in the anterior wall 56 of the capsule 20. Lens 30 is then folded into a compact size for insertion into the capsule 20 through the opening 58. Once inserted, the capsule 20 is filled with fluids (e.g., saline

solution) which enter the chamber 48 of the lens 30, causing the lens 30 to return to its original, non-deformed state as shown in FIGS. 1 and 3. There is no need to suture the lens 30 to the capsule 20 because, due to the size and shape of the lens 30 as described above, the lens 30 will not rotate or shift within the capsule 20.

[0036] Implantation of the inventive lens 30 restores normal vision because, not only does the lens 30 replace the patient's occluded natural lens, but the normal responses of the ciliary body 24 cooperate with the lens 30 during focusing. In FIG. 1, the capsule 20 is shaped for viewing an object distant from the eye 10. That is, in order to view an object distant from the viewer, the ciliary body 24 has retracted, thus pulling on the zonular fibers 26, making the capsule 20 (and thus the lens 30) more discoid in shape. This change in shape causes the optic 32 to become thinner (i.e., there is a decrease in the horizontal depth of the optic 32) so that it has a thickness T_D . As used herein, the thickness of the optic is intended to be the thickness at approximately the center of the optic.

[0037] Optic 32 is formed of a solid, liquid, or gel material (e.g., silicone) so it has a refractive index greater than that of the surrounding fluid in the eye (i.e., greater than 1.33). This refractive index, combined with the thinness of optic 32 as shown in FIG. 1, results in a less convergent lens which makes distance viewing possible.

[0038] Referring to FIG. 2, the ciliary body 24 has contracted, making the capsule 20 more spheroid in shape. As a result, the optic 32 has had an increase in thickness to a thickness of T_N . The thickness increase should be such that T_N is at least about 1.1 times, preferably at least about 1.2 times, and more preferably from about 1.2-1.4 times that of T_D when a force of from about 1-9 grams, and preferably from about 6-9 grams, is applied to the optic positioning element (more specifically, to the outer edges of the optic positioning element or around the equatorial region of the optic positioning element). As used herein, the force is a measure of an inwardly directed force in the plane of the equator equally distributed over 360 degrees around the equator.

[0039] This increase in optic thickness combined with the fact that the refractive index of the optic 32 is greater than 1.33 (and preferably at least about 1.36, more preferably at least about 1.4, and even more preferably at least about 1.5) results in an increased convergence of light, thus enabling the eye to see objects near the viewer. The lens 30 thus follows the eye's natural physiology for focusing to provide a substitute means of optical accommodation.

2. Embodiment of FIGS. 4-5

[0040] While the anterior surface 34 and the posterior surface 36 of the lens 30 of FIGS. 1-3 are both convex, the shapes of these surfaces can be varied depending upon the user's eyesight. One such variation is shown in FIGS. 4-5.

[0041] FIGS. 4-5 show a lens 70 which is similar in construction to the lens 30 of FIGS. 1-3 with the exception of the optic construction. That is, lens 70 includes a plano-convex optic 72. The optic 72 comprises a planar anterior surface 74 and a convex posterior surface 76. Lens 70 operates to provide accommodation in the same manner as discussed above with respect to lens 30.

3. Embodiment of FIGS. 6-7

[0042] FIGS. 6-7 show a lens 78 which is similar in construction to the lens 30 of FIGS. 1-3 with the exception of the optic construction. Lens 78 includes an optic 80 whose cross-section is meniscus in shape. That is, the optic 80 comprises a concave anterior surface 82 and a convex posterior surface 84 so that the curves of surfaces 82, 84 follow the same general direction of curvature. Lens 78 operates to provide accommodation in the same manner as discussed above with respect to lens 30.

4. Embodiment of FIGS. 8-9

[0043] FIGS. 8-9 show a lens 86 which is also similar in construction to the lens 30 of FIGS. 1-3 with the exception of the optic construction. Lens 86 includes an optic 88 whose cross-section is meniscus in shape. That is, the optic 88 comprises a concave anterior wall 90 and a convex posterior wall 92 so that the curves of walls 90, 92 follow the same general direction of curvature.

[0044] While lens 86 includes a meniscus-shaped optic 88 like that of the embodiment of FIGS. 6-7, the optic 88 is very different from optic 80 of lens 78 in that optic 88 is gas-filled. That is, walls 90, 92 cooperate with endwalls 94a,b to form a chamber 96. Chamber 96 is filled with a gas. While any biologically safe gas is acceptable, the preferred gas is simply air. Also, walls 90, 92 and endwalls 94a,g can be formed of the same materials described previously with respect to optic and optic positioning element materials.

[0045] Although lens 86 has a gas-filled optic 88 rather than a solid optic, lens 86 still operates to provide accommodation in a somewhat similar manner as discussed above with respect to lens 30. In more detail and referring to FIG. 8, the lens 86 is shaped for viewing an object distant from the viewer. That is, in order to view an object distant from the viewer, the ciliary body (not shown) has retracted, thus pulling on the zonular fibers and making the lens 86 more discoid in shape. This change in shape causes the optic 88 to become thicker (i.e., there is an increase in the horizontal depth of the optic 88 or there is an increase in the distance between wall 90 and wall 92) so that the optic 88 has a thickness T_d . However, because optic 88 is filled with a gas, a thicker optic 88 results in a lesser convergence of light because the gas has a refractive index which is lower than the refractive index of the fluids in the eye (i.e., less than about 1.3, preferably less than about 1.2, and more preferably less than about 1.0), thus making optic 88 suitable for distance viewing.

[0046] Referring to FIG. 9, the ciliary body (not shown) has contracted, making the lens 86 more spheroid in shape. As discussed with previous embodiments, a solid optic would incur an increase in thickness as a result of the contraction. However, due to the fact that optic 88 is gas-filled, the distance between wall 90 and wall 92 decreases, thus causing optic 88 to have a decrease in thickness to a thickness of T_n . This decrease in optic thickness results in an increased convergence of light, thus enabling the eye to see objects near the viewer. Thus, the thickness decrease when a force of from about 1-9 grams, and preferably from about 6-9 grams, is applied to the optic positioning element (more specifically, to the outer edges of the optic positioning element or around the equatorial region of the optic positioning element) should be such that T_d is at

least about 1.2 times, preferably at least about 1.3 times, and more preferably from about 1.3-1.35 times that of T_n .

5. Embodiment of FIG. 10

[0047] FIG. 10 shows a lens 100 which is similar in overall construction to the lens of FIGS. 8-9 except that lens 100 includes a biconcave optic 102. Optic 102 includes an anterior, concave wall 104, a posterior concave wall 106, and a pair of endwalls 108a,b. Walls 104 and 106 cooperate with endwalls 108a,b to form gas-filled chamber 110 which is filled with a biologically safe gas such as air. The lens 100 operates to provide accommodation in a manner similar to that described with respect to lens 86 of FIGS. 8-9.

6. Embodiment of FIG. 11

[0048] FIG. 11 shows a lens 120 which is constructed in a manner similar to that of the preceding lens embodiments with the exception of the optic construction. Lens 120 includes a combination optic 122 which combines aspects of the optics shown in FIGS. 1-7 with the type of optic disclosed in FIGS. 8-10. That is, the optic 122 comprises a biconvex, solid optic 124 and a gas-filled optic 126. Optic 124 includes a convex, anterior surface 128 and a convex posterior surface 130. Optic 126 includes a convex, posterior wall 132 and endwalls 134a,b which cooperate with convex posterior surface 130 of optic 124 to form a gas-filled chamber 136. Again, any biologically safe gas is acceptable, although air is preferred.

[0049] The lens 120 operates to provide accommodation in a manner similar to that described with respect to lens 86 of FIGS. 8-10. That is, the gas-filled optic 126 will become thinner, and the solid optic 124 may become thicker upon contraction of the ciliary body, thus causing an increased convergence of light to allow for near viewing. Upon retraction of the ciliary body, the opposite will occur. That is, the lens 120 will become more discoid in shape so that the gas-filled optic 126 will become thicker while the solid optic 124 will become thinner, thus causing a decreased convergence of light to allow for distance viewing.

7. Embodiment of FIGS. 12-14

[0050] FIGS. 12-15 illustrate embodiments where a different type of optic positioning element is utilized. Referring to FIGS. 12-13, the lens includes an optic 142 and an optic positioning element 144. Optic 142 can be of any known optic construction, or it can be any of the inventive optics disclosed herein.

[0051] Optic positioning element 144 comprises a skirt 146 which includes a plurality of radially extending elements 148. In the embodiment shown, elements 148 comprise respective openings 150. The respective sizes and shapes of openings 150 are not critical so long as they are capable of allowing fibrosis of the tissue. Furthermore, openings 150 can be omitted if desired.

[0052] Elements 148 are joined to one another by thin membranes 152. Alternately, optic positioning element 144 can simply include a circular or disc-shaped haptic having a substantially uniform thickness (i.e., rather than thicker radially extending elements 148 and thinner membranes 152) extending from the optic.

[0053] Elements 148 and membranes 152 are generally formed of the same material (e.g., silicones, acrylates) but

with a difference in thicknesses, although the material can be different, and the selection of material is not critical so long as it is biologically safe and at least somewhat resilient. It will be appreciated that the respective thicknesses of elements 148 and membranes 152 can be adjusted as necessary by one of ordinary skill in the art. Ideally, the elements 148 will be of sufficient respective thicknesses to provide resistance to the force created on the outer edges 154 of the elements 148 by the contraction of the ciliary body. The respective thicknesses of the membranes 152 should be such that the flexibility of the overall skirt 146 is maintained while being resistant to tearing.

[0054] FIG. 14 shows one type of possible optic construction for use with this type of optic positioning element 144. In this embodiment, lens 160 is shown within a capsule 20 of an eye. The optic 142 includes a posterior convex surface 156 and an anterior convex surface 158. In the embodiment shown, optic 142 is integrally formed with elements 148, although this is not mandatory. Finally, FIG. 14 demonstrates the formation of fibrin 160 (fibrosis) through openings 150.

[0055] Lens 140 would operate to provide accommodation in a manner similar to that described with respect to lens 30 of FIGS. 1-3. That is, the ciliary body (not shown) would retract or contract as necessary, thus either pulling on the zonular fibers 26 or releasing the pull on the zonular fibers 26. Due to the fibrin 160 formed through openings 150, this would necessarily result in an outward force on elements 148 (resulting in the thinning of optic 142) or the release of that outward force (resulting in the thickening of optic 142). Because optic 142 is formed of a material having a refractive index of greater than 1.33, thickening of optic 142 would result in increased convergence of light for near viewing and thinning of optic 142 would result in decreased convergence of light for distance viewing.

8. Embodiment of FIG. 15

[0056] FIG. 15 shows another lens according to the invention. This lens is constructed similarly to that of FIGS. 12-14 except that a different optic is utilized. Specifically, lens 170 comprises a combination optic 172 and an optic positioning element 174. Optic positioning element 174 is similar to optic positioning element 144 of FIGS. 12-14 in that it includes a plurality of radially extending elements 176 connected via thin membranes (not shown). Combination optic 172 comprises a biconvex optic 178 and a meniscus optic 180. Biconvex optic 178 includes a convex, anterior surface 182 and a convex, posterior surface 184. Optic 180 includes a concave, anterior wall 186 and a convex, posterior wall 188.

[0057] The lens 170 of FIG. 15 is particularly unique in that each of the optics 178 and 180 of the combination optic 172 is prepared in a different state of accommodation. In the embodiment shown, optic 180 is formed in the disaccommodated state while the optic 178 is formed in the accommodated state. Due to strength differences, optic 180 has the greater influence when it is joined with optic 178. Thus, the overall combination optic 172 will rest in, or default to (absent a counteracting external force), the disaccommodated state due to the fact that optic 180 will stretch optic 178 to the disaccommodated state.

[0058] When the ciliary body (not shown) retracts or contracts as necessary (either pulling on the zonular fibers or

releasing the pull on the zonular fibers), the fibrin (not shown) formed through openings 150 would result in a radially outward force on elements 176 (resulting in the thinning of optics 178, 180) or the release of that outward force (resulting in the thickening of optic 178, 180). Because optics 178, 180 are formed of materials (either the same or different) having respective refractive indices of greater than 1.33, thickening of optics 178, 180 would result in an increased convergence of light for near viewing, and thinning of optic 178, 180 would result in a decreased convergence of light for distance viewing.

[0059] Each of the foregoing embodiments can be used to obtain an accommodation improvement of at least about 1.5 diopters, preferably at least about 3.0 diopters, and more preferably from about 4-8 diopters. "Diopter" is defined as the reciprocal of the focal length in meters:

$$\text{Diopter} = 1/\text{focal length (m)}.$$

[0060] Focal length is the distance from the center of the lens to the object being viewed.

[0061] Importantly, this accommodation can be achieved with very little force being required by the eye. That is, the typical eye exerts anywhere from about 6-9 grams of force on an intraocular lens. However, the inventive optic can be designed to change shape sufficiently to produce the desired accommodation with as little as 1 gram of force. Thus, lenses according to the present invention provide a further advantage in that they can be designed to respond to a force over the entire range of from about 1 to about 9 grams.

[0062] For each of the foregoing embodiments illustrated in FIGS. 1-15, examples of suitable materials of which the lens and lens components (e.g., optic positioning elements, optics) can be constructed include any yieldable, synthetic resin material such as acrylates (e.g., polymethylmethacrylates), silicones, and mixtures of acrylates and silicones. It is particularly preferred that the optic positioning elements be constructed of a material having an elastic memory (i.e., the material should be capable of substantially recovering its original size and shape after a deforming force has been removed). An example of a preferred material having elastic memory is MEMORYLENS (available from Mentor Ophthalmics in California).

[0063] Furthermore, the optics of each embodiment could be formed of a wide range of flexible, refractive materials so long as the necessary thickening or thinning thereof can be achieved. Suitable materials include gels, silicone, silicone blends, refractive liquids, elastomeric materials, rubbers, acrylates, gases such as air, and mixtures of the foregoing, so long as the material is flexible and resilient. The shape of the optic (e.g., meniscus, biconcave, biconvex) utilized will depend upon the refractive index of the material used to form the optic. That is, the combination of optic shape and optic material will need to be chosen so that the resulting lens will converge light when the ciliary body contracts for near viewing.

[0064] While the foregoing description shows certain types of optic positioning elements with certain optics (both optic shapes and optic materials), it will be appreciated that this is for illustration purposes only, and the optic positioning elements and optic types can be switched. For example, the combination optic 172 of FIG. 15 could be utilized with

the optic positioning element 33 of FIG. 1, the optic 32 of FIG. 1 could be utilized with the optic positioning element 144 of FIG. 12, etc.

[0065] Although the invention has been described with reference to the preferred embodiments illustrated in the attached drawing figures, it is noted that equivalents may be employed and substitutions made herein without departing from the scope of the invention as recited in the claims. For example, while the foregoing method of inserting the lens into the capsule presumed that a portion of the anterior wall of the capsule would be removed with the natural lens, it will be appreciated that it may be possible to insert the lens through an incision in the anterior wall. Furthermore, while the foregoing description discloses that the inventive lenses could be utilized in cataract patients, the lenses may be used in any situation where the natural lens needs to be replaced. For example, the inventive lenses may be used to correct myopia, hyperopia, presbyopia, cataracts, or a combination thereof.

[0066] Finally, it will be appreciated that each of the foregoing lenses can be manufactured in either the accommodated or disaccommodated shape. That is, they can be manufactured in a default state of either an accommodated or disaccommodated shape, and the deformed state (i.e., the state caused by the forces within the eye during focusing) will be the other of the accommodated or disaccommodated shape.

I claim:

1. In an accommodating intraocular lens for implantation within an eye, said lens comprising an optic having an initial thickness and an optic positioning element coupled with said optic, the improvement being that said optic initial thickness can be altered in response to a change in force on said optic.

2. The lens of claim 1, said optic positioning element being formed of a yieldable synthetic resin material.

3. The lens of claim 2, said optic positioning element being formed of a material comprising a compound selected from the group consisting of silicon, polymethylmethacrylates, and mixtures thereof.

4. The lens of claim 1, said optic positioning element comprising a posterior face, an anterior face, and a bight, said anterior face, said posterior face, and said bight cooperating to form a chamber within said optic positioning element.

5. The lens of claim 4, wherein said optic positioning element posterior face or anterior face includes an opening therethrough, said opening communicating with said chamber.

6. The lens of claim 1, wherein said optic positioning element comprises a disc-shaped body, and said optic is positioned approximately in the center of said body.

7. The lens of claim 6, wherein said disc-shaped body comprises at least two radially extended flanges.

8. The lens of claim 7, wherein said flanges are joined to one another by respective membranes.

9. The lens of claim 8, wherein said flanges have respective thicknesses and said membranes have respective thicknesses, each of said flange thicknesses being greater than each of said membrane thicknesses.

10. The lens of claim 6, wherein said disc-shaped body has a horizontal plane, and said optic lies along said horizontal plane.

11. The lens of claim 6, wherein said disc-shaped body has a horizontal plane, and said optic lies outside said horizontal plane.

12. The lens of claim 1, wherein said optic initial thickness can be increased in response to ciliary body contraction.

13. The lens of claim 12, wherein said optic initial thickness can be increased to a second thickness in response to ciliary body contraction, said second thickness being at least about 1.1 times greater than said initial thickness.

14. The lens of claim 12, wherein said optic is formed of a material having a refractive index of at least about 1.36.

15. The lens of claim 14, wherein said optic has a cross-sectional shape selected from the group consisting of biconvex, meniscus, and planoconvex shapes.

16. The lens of claim 1, wherein said optic initial thickness can be decreased in response to ciliary body contraction.

17. The lens of claim 16, wherein said optic initial thickness can be decreased to a second thickness in response to ciliary body contraction, said initial thickness being at least about 1.2 times greater than said second thickness.

18. The lens of claim 1, wherein said optic comprises a gas-filled chamber.

19. The lens of claim 16, wherein said optic is formed of a material having a refractive index of less than about 1.2.

20. The lens of claim 19, wherein said optic has a cross-sectional shape selected from the group consisting of meniscus, biconcave, and planoconcave shapes.

21. In an accommodating intraocular lens for implantation within an eye, said lens comprising:

a pair of optics immediately adjacent one another; and

an optic positioning element coupled with at least one of said optics.

22. The lens of claim 21, wherein one of said optics is formed of a material selected from the group consisting of refractive solids, liquids, and gels, and the other of said optics comprises a gas-filled chamber.

23. The lens of claim 21, wherein one of said optics has a refractive index of at least about 1.36, and the other of said optics has a refractive index of less than about 1.2.

24. The lens of claim 21, wherein both of said optics is formed of a material selected from the group consisting of refractive solids, liquids, and gels.

25. The lens of claim 21, wherein both of said optics have a refractive index of at least about 1.36.

26. The lens of claim 21, said optic positioning element being formed of a yieldable synthetic resin material.

27. The lens of claim 26, said optic positioning element being formed of a material comprising a compound selected from the group consisting of silicone, polymethylmethacrylates, and mixtures thereof.

28. The lens of claim 21, said optic positioning element comprising a posterior face, an anterior face, and a bight, said anterior face, said posterior face, and said bight cooperating to form a chamber within said optic positioning element.

29. The lens of claim 28, wherein said optic positioning element posterior face or anterior face includes an opening therethrough, said opening communicating with said chamber.

30. The lens of claim 21, wherein said optic positioning element comprises a disc-shaped body, and said optic is positioned approximately in the center of said body.

31. The lens of claim 30, wherein said disc-shaped body comprises at least two radially extended flanges.

32. The lens of claim 31, wherein said flanges are joined to one another by respective membranes.

33. The lens of claim 32, wherein said flanges have respective thicknesses and said membranes have respective thicknesses, each of said flange thicknesses being greater than each of said membrane thicknesses.

34. The lens of claim 30, wherein said disc-shaped body has a horizontal plane, and said optic lies along said horizontal plane.

35. The lens of claim 30, wherein said disc-shaped body has a horizontal plane, and said optic lies outside said horizontal plane.

36. A method of providing accommodation to an eye comprising a ciliary body and whose natural lens has been removed, said method comprising the step of implanting an intraocular lens into the eye, said lens comprising an optic having an initial thickness which can be altered on response to movements of said ciliary body.

37. The method of claim 36, said eye having a retina and further including the step of contracting said ciliary body, said contracting step causing said optic initial thickness to change so as to increase convergence of light to the retina.

38. The method of claim 37, wherein said optic is formed of a material having a refractive index of greater than about 1.36, and said contracting step causes said optic thickness to increase.

39. The method of claim 38, wherein said increased optic thickness is at least about 1.1 times more than said initial optic thickness.

40. The method of claim 37, wherein said optic is formed of a material having a refractive index of less than about 1.2, and said contracting step causes said optic thickness to decrease.

41. The method of claim 40, wherein said initial optic thickness is at least about 1.2 times more than said decreased optic thickness.

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