MULTI-FOCAL INTRAOCULAR LENS

The invention relates to intraocular lenses for the human eye and, particularly, to multifocal lenses of this type which can bring images of objects located at different distances into focus on the retina simultaneously.

BACKGROUND OF THE INVENTION

FIG. **1** illustrates a human eye in cross-section, showing cornea **13**, iris **16**, and lens **19**. The lens **19** can suffer disease, such as a cataract, in which case surgical removal of the lens may be necessary. After removal, the lens can be replaced by an artificial lens **22**, shown in FIG. **2**, and which is termed an intraocular lens (IOL). The IOL restores much of the visual acuity of the eye, but has the characteristic of focusing upon the retina only those objects, such as object **29**, which are within the depth of field **25** of the focusing system, which includes the IOL **22** and the cornea **13**. Other objects, such as object **31** located in the far field **27**, are not in focus, and thus appear blurred.

A prior art device which appears to mitigate this problem is discussed in U.S. Pat. No. 4,636,211 (Nielsen et al.) The Nielsen patent discusses a bifocal IOL as shown in FIG. **3**. The Nielsen patent states that "the one piece body has a centrally located optically powered portion for near vision, designated as number **3**, which is surrounded by a far vision optically powered portion **2**, the two portions being concentric and coaxial."

The Nielsen patent further states that the difference in focusing power between the near vision region **3** and the far vision region **2** should be about 2.50 diopters.

The Nielsen lens, when used as IOL **22** in FIG. **2**, focuses both the near-field object **29** and the far-field object **31** simultaneously upon the retina **28**. Because the focus of both images differ by 2.50 diopters, the human visual system is able to reject one of the images and view the image which is preferred.

A disadvantage of the Nielsen approach occurs in the presence of bright light. Nielsen states that the diameter **40** in FIG. **3A** of the near vision region **3** should be 2.12 millimeters (mm). This diameter is only slightly larger than the diameter **42** in FIG. **4** of the fully constricted pupil **44** of the average human eye when exposed to bright light. In such a situation, the fully constricted pupil prevents adequate incoming light **46** from reaching the far vision region **2** of Nielsen's lens, causing the image of the far field object **31** in FIG. **2** to become very dim on the retina **28**. The fully constricted pupil inhibits clear vision of the far field object **31**.

Further, even if the pupil does not fully constrict (i.e., the iris **16** does not fully cover Nielsen's far vision region **2** as assumed in the paragraph above), some visual distortion will probably occur. For example, the unblocked, or exposed, part of region **2** of the IOL will resemble annulus **47** in FIG. **5**. The annulus **47** is reduced in height, which is indicated by dimension **49**, which causes a reduction in cross-sectional area, which, in turn, reduces the amount of light which the annulus can collect.

This reduction in collected light causes the far field image (focused by the annulus) to be less bright than the near field image (focused by region **3**). It is believed that this difference in brightness will cause the far field image to be overpowered by the brightness of the near field image, rendering the far field image useless.

The degradation of the far field image just described occurs at a time when objects in the far field are of greatest interest. That is, the bright light, which is responsible for the contraction of the pupil, is generally experienced during outdoor activities, when people are interested in viewing distant objects. However, as just shown, the pupil constriction can obstruct the far-vision region of the IOL and cause distortion or loss of distance vision.

OBJECT OF THE INVENTION

It is an object of the present invention to provide an improved intraocular lens.

It is a further object of the invention to provide an improved intraocular lens which can provide appropriate vision under a wide range of lighting conditions.

It is a further object of the invention to provide an improved intraocular lens which can focus objects at different distances from the eye in which the lens is implanted.

It is a further object of the invention to provide an improved intraocular lens which has bifocal capability, and, further, the ability to focus far field objects in bright light, when the pupil of the eye is constricted.

SUMMARY OF THE INVENTION

In one form of the invention, an intraocular lens contains three concentric regions. An innermost region provides far-field vision. A middle region, surrounding the innermost region, provides near-field vision. An outermost region, surrounding the middle region, provides far-field vision. The innermost region is of a size such that, when the pupil constricts in bright light, the innermost region remains exposed to incoming light, and can thus focus distant images in bright light.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** illustrates a human eye in cross section.

FIG. **2** illustrates an intraocular lens which can replace the natural lens **19** in FIG. **1**.

FIGS. **3A** and **3B** illustrate a type of bi-focal intraocular lens found in the prior art.

FIGS. **4** and **5** illustrate obstruction of region **2** of the prior art lens of FIG. **3** which occurs when the pupil **44** constricts in bright light.

FIG. **6** illustrates one form of the invention.

FIG. **7** illustrates the invention of FIG. **6** when implanted in the eye.

FIG. **8** illustrates several alternate embodiments of the invention.

FIG. **9** illustrates, in exaggerated form, the lens of FIG. **3A** in cross-section.

FIG. **10** illustrates a type of lens blank from which the embodiment of FIG. **6** can be manufactured.

FIG. **11** illustrates the cross-section of a lens manufactured from the blank **65** in FIG. **10**.

FIG. **12** illustrates three different types of lens which can be used as the lens of FIG. **6**.

FIGS. **13A** and **13B** illustrate different regions of the lens of FIG. **6** which are exposed under different lighting conditions.

FIG. **14** illustrates a lens of the present invention, including haptic members which are used to support and center the lens in the eye.