

INTRAOCCULAR LENS

BACKGROUND OF THE INVENTION

This invention relates to an artificial intraocular lens for insertion into the eye, for example to replace the natural lens after it has been removed because of injury or cataract.

A typical artificial intraocular lens (IOL) is fabricated of a clear, rigid, hydrophobic plastic material, usually polymethylmethacrylate (PMMA), to form an optical element with two curved faces. The IOL is typically implanted by inserting it via the same corneal or sclerotic incision used to remove the natural lens.

Conventionally, the IOL provides a single refractive power (for example, about +20 diopters) to focus images on the retina. The refractive power is determined by the relative indices of refraction of the eye's aqueous humor (1.34) and the lens material (1.50 in the case of PMMA) and the radii of curvature of the front and rear faces of the lens.

The IOL can be implanted either in the anterior chamber (located between the iris and cornea) or the posterior chamber (behind the iris). Because the IOL is typically both smaller and more dense than the natural lens, it must be held in place either by clipping it directly to the iris or suspending it by attachment fixtures, called haptics.

Various techniques have been proposed (a) to provide an IOL with a refraction power that can be changed to accommodate to distance or close-up viewing, (b) to render the IOL expandable to permit implantation of the contracted IOL via a small incision, and (c) to impart neutral buoyancy to the IOL.

SUMMARY OF THE INVENTION

The general feature of the invention is an IOL having an optical body that refracts images received via the cornea, and an outer surface that encloses the optical body, is exposed to fluid within the eye, and has a refractive index no greater than 1.40. The lens suppresses internal reflections and the refractive power of the lens can be made to be largely independent of the external configuration of the lens.

Preferred embodiments include the following features. The outer surface is a hydrogel polymer having an equilibrium water content of at least 65%, preferably at least 75%, most preferably at least 90%. The polymer is a hydrophilic derivative of polyacrylic or polymethacrylic acid, for example a copolymer containing hydrophilic and hydrophobic groups organized in continuous sequences. The hydrogel is covalently cross-linked. The outer surface includes ionized negatively charged groups. The optical body has an outer layer on which the outer surface lies, and an inner layer of different refractive index from the outer layer, the inner and outer layers meeting at an interface, refraction by the lens occurring primarily (e.g., more than 50%) at the interface.

The outer layer is a swellable material that has a gradient of swellability that decreases from a maximum value at the outer surface. The optical body has a plurality of layers comprising materials of different refractive index, the layers being defined by surfaces a plurality of which have the same radius of curvature. The optical body has an inner layer (e.g., fluid) having front and rear optical faces, and an outer layer enclosing the inner layer, the outer surface of said lens having front and

rear exposed optical surfaces on the outer layer, the outer layer comprising two internal optical faces that respectively cooperate with the front and rear optical faces of the inner layer to define a pair of refractive interfaces, the inner and outer layers comprising materials of different refractive index. The fluid is a gas having a composition corresponding to the partial pressure of gases dissolved in the intraocular medium. At least one of the refractive interfaces is convex or concave, or is a Fresnel-like surface, or is planar.

In some embodiments, the contour of the outer surface, and the front-to-back thickness of the lens, are the same as for a natural lens. In some embodiments, the lens can be temporarily altered in shape to permit it to be inserted through a 4 mm² corneal incision. In some embodiments, the outer layer has a pair of fluid filled chambers located respectively in front of and behind the inner layer. The chambers are inflatable following implantation by absorption of water from the intraocular medium through the outer surface and into a dehydrated hydrophilic material in the chamber. In some embodiments, a rigid, resilient ring defines the perimeter of the optical body, the outer layer comprising a pair of films formed on and spaced apart by the ring, and the inner layer being defined between the respective internal faces of the films. There is a spacer peg having its ends in contact with the internal faces for resisting movement of the films toward each other caused by intraocular pressure. The peg is positioned on the optical axis of the eye.

In some embodiments, the optical body comprises means for imparting different selective refractive powers to the lens. The optical body has an enclosed chamber and the means for imparting includes fluids of different refractive index and a means for supplying volumes of the fluids to the chamber. When two fluids are used they are immiscible and of different density. One fluid is saline. The means for imparting includes a pair of layers within the optical body separated by a flexible interface, and a means for shifting the contour of the interface. The pair of layers comprise a chamber and the interface comprises a membrane that divides the chamber into two subchambers, and the means for shifting comprises a means for pumping selectable volumes of fluid into the subchambers. The pump comprises a membrane, and a magnet cooperating with the membrane, the magnet being positioned to interact with an external magnet placed in proximity to the cornea of the eye.

The lens has a central optical zone larger than 5 mm, a selective refractive power (when implanted) of between +5 and +30 diopters, a refractive index no greater than 1.35, a thickness before implantation between 0.2 and 1 mm and after implantation between 1 and 5 mm, a diameter of the optical portion between 6 and 9 mm, and a density between 0.95 and 1.05 (preferably between 0.98 and 1.02). The ratio of the lens refractive power in air to its refractive power when implanted is lower than 3, preferably lower than 1.5.

A second general feature of the invention is a lens in which the contour of an internal refractive surface is changed to change its refractive power.

Preferred embodiments include the following features. The internal refractive surface is a membrane separating two fluid-containing chambers and the fluid volumes or pressures are changed to switch the membrane from convex to concave. The fluids are supplied from two containers having flexible walls to change the