# ENCAPSULATED ACCOMMODATING INTRAOCULAR LENS

## BACKGROUND

1. Field of Invention

This invention relates to intraocular lenses, specifically to such intraocular lenses as can be used to restore accommodation.

2. Description of Prior Art

Cataract surgery typically involves removing the cataractous natural lens and replacing it with an artificial intraocular lens. These artificial intraocular lenses, in most cases, have one fixed focus, or in some cases, a few fixed foci. This means that these intraocular lenses lack the natural lens' ability to accommodate. That is to say, they lack the ability to adjust their power over a continuous range. This means that they are not able to bring to a sharp focus light rays coming from objects over a continuous range of distances.

In the normal case the eye accommodates by having the ciliary muscle cause the crystalline lens to alter its shape. The amount of muscle power available is highly limited. Also, the amount of movement generated in the course of accommodation is quite small. Therefore, it is highly desireable for an accommodating intraocular lens to have high gain. By "high gain" is meant that small changes in position, shape, or force are capable of creating large changes in optical power.

In the case of an intraocular lens which accommodates by altering its shape, high gain may be achieved by utilizing different optical materials with substantially different refractive indices.

The optical power of a single spherical surface separating two materials with different refractive indices is given by the formula:

$$P=(n'-n)/r$$

where P denotes lens power, r denotes the radius of curvature of the spherical surface and n' and n denote the refractive indices in the two optical materials. This formula shows that, for a given radius of curvature, the power is proportional to the difference in refractive indices, i.e. to the difference between n' and n. In order to better realize how the magnitude of the difference in refractive indices affects the changes in lens power as a result of change in lens shape we take the derivative of this function:

$$dP/dr=-(n'-n)/r^2$$

which means that the change in lens power created by a given change in curvature (i.e. shape) is proportional to the magnitude of the difference in refractive indices across the surface. In other words, in order to obtain high gain (i.e. large change in power for small changes in surface shape) it is important to have optical materials with highly different refractive indices [i.e. to have the magnitude of (n'−n) be large].

The refractive index of the aqueous, i.e. the liquid filling the eye, is close to that of water which is about 1.33. Most fluids have refractive indices which are relatively similar to this value. This means that by relying on the interface between one of these materials and aqueous, relatively large shape changes are needed in order to significantly alter the overall power of the lens.

U.S. Pat. No. 5,489,302 to Skottun has described the use of a gas, e.g. room-air, as a refractive medium. Gases



typically have a refractive index of 1.0, which is substantially different from the 1.33 of water. Thus, a lens using a gas as the optic medium may be able to generate substantial changes in optical power with the application of a relatively small force and small degrees of movement.

Additionally, using a gas has the advantage of allowing the intraocular lens to be lightweight and to have little mass. Light weight and little mass make the intraocular lens exert little stress on the delicate internal structures of the eye, thereby reducing the likelihood that the intraocular lens will cause damage to the intraocular environment.

Unfortunately, using a gas as a medium is not without difficulties. One potential problem is that a gas is compressible, thus making a lens using gas as its optic medium potentially susceptible to changes in intraocular pressure. That is to say, changes in intraocular pressure could potentially alter the optical power of such a lens.

Another potential problem is that thin and flexible membranes, such as are likely to used in a lens, may not be gas impermeable. An accommodating intraocular lens using gas as its optical medium will need to be able to have a flexible and transparent interface between the gas and another fluid medium. In order to be sufficiently flexible this interface will need to be fashioned out of a membrane. This membrane needs to be thin, transparent and flexible. Thin and flexible membranes tend not to be gas impermeable. Thus, it is possible that there will be some amount of gas exchange between the gas inside the intraocular lens and the surrounding aqueous. This may cause a net transport of gas either into (i.e. dissolved gases in the aqueous moving into the intraocular lens) or out of (i.e. gas moving from the lens into the aqueous) the intraocular lens.

## ADVANTAGES

The main advantages of the present invention are:

(a) to provide an accommodating intraocular lens which may use a gas as an optical medium.

(b) to provide an accommodating intraocular lens which is insensitive, or only minimally sensitive, to changes in intraocular pressure.

(c) to provide an accommodating intraocular lens which may use a gas as an optical medium in which the gas inside the intraocular lens is separated from the surrounding aqueous in such a manner so as to prevent, or substantially limit, transfer of gas between the inside of the intraocular lens and the surrounding aqueous.

(d) to provide an accommodating intraocular lens which has high gain.

Further advantages of the present invention are to be light in weight and to have little mass. Also, it will have the advantage of being simple to insert into the eye so as to not require exceptional skills on the part of the surgeon. Additional advantages and objectives will become apparent from a consideration of the ensuing description and drawings.

## DRAWING-FIGURES

FIGS. **1**A to **1**B illustrate the basic principle of the encapsulated accommodating intraocular lens.

FIG. **2** shows a cross section through the encapsulated intraocular lens.

FIG. **3** shows a cross section through the encapsulated intraocular lens after it has been made to increase its power.

FIG. **4** shows a frontal view of the encapsulated intraocular lens.

FIG. **5** shows a side view of the encapsulated intraocular lens.