FLUID FILLED AND PRESSURIZED LENS WITH FLEXIBLE OPTICAL BOUNDARY HAVING VARIABLE FOCAL LENGTH

FIELD OF THE INVENTION

The present invention relates to variable focal length lenses, and in particular to a fluid filled lens having a flexible optical membrane or surface boundary, the optical properties of which can be controlled by the pressure of the fluid within the boundaries. The curvature of the optical surface boundaries of the lenses so formed can be adjusted and controlled at will. The pressure within the boundaries is the pressure difference across the optical surface boundary.

BACKGROUND OF THE INVENTION

Adjustable optical surface curvature lenses having variable focal length are known in the prior art. Eyewear lenses are one application for which variable focal length lenses can be used.

Such variable focal length lenses are particularly useful for compensation of loss of accommodation of the human eye. Loss of accommodation is the loss of the ability to adjust the focal length of the eye to view objects at varying distances. Typically, bifocal and trifocal ground lenses have been used to compensate for the loss of accommodation. However, such ground lenses provide compensation only at specific fixed object distances, such that objects located between the two fixed distances of a bifocal lens (or the three fixed distances of a trifocal lens) still require some human eye accommodation in order for the user to focus on that object.

One type of adjustable curvature lens is a fluid filled and pressurized flexible optical membrane or surface boundary variable focal length lens. Fluid filled and pressurized variable focal length lenses can compensate for loss of accommodation by providing a lens that can focus on objects at any distance. In a fluid filled and pressurized variable focal length lens, typically two elastomeric optical surface forming membranes are held in alignment at their peripheries and the cavity therebetween is filled with a transparent refractive fluid. The pressure of the fluid within the cavity causes deformation of the membranes, which in turn causes a change in the shape of the refractive fluid boundaries, which in turn causes variations in the focal length of the lens. Therefore, fluid filled and pressurized variable focal length lenses provide an advantage over ground lenses, and provide focus on objects at any distance.

Fluid filled and pressurized variable focal length lenses offered by others, however, suffer optical aberrations due to:

1) The optical surface forming membrane itself, and
2) The support constraints introduced around the edge portions of the membrane.

Regarding optical aberrations due to the membrane itself; the optical aberrations originate with the thickness profile (cross-sectional thickness from edge to edge) of the membrane. A membrane made of a flat plate cannot form a spherical surface when deformed by fluid pressure. This is true even with a simple support around the edge of the membrane. My invention solves this problem by changing the thickness profile from the center of the membrane to the edge. The thickness profile does not have a constant thickness as with a flat membrane, but instead has a reduction in thickness as a function in distance from the center as defined by the most advantageous curve, typically and simplistically a conic section.

Regarding optical aberrations due to the support constraints around the membrane, edge moments induced by other approaches cause bending of the membrane to shapes not purely dependent on the fluid pressure. In some cases, edge slope is fixed, often at zero slope (that is, the membrane edge does not bend). Thus, as the center of the membrane flexes due to fluid pressure, the membrane edges are restrained and are unable to form spherical shapes as required in spherical optics. The prior art retaining arrangements subject the membrane edge to retarding edge moments so that the edges do not flex to form an advantageous optical shape. The optical aberrations caused by the fixed and restrained membrane edges work to limit the effective field of view of the fluid filled and pressurized variable focal length lens, reducing the usefulness of the lens substantially. Ideally, the elastic lens elements of a fluid filled and pressurized variable curvature focal length lens should assume a spherical shape upon pressurization and subsequent deformation in response to fluid presence within the cavity of the lens.

Another source of optical aberrations in a fluid filled variable focus lens is the presence of a contaminating fluid inside of the lens. Such a contaminating fluid has different optical properties than the refractive fluid that is used to deform the membranes and pass light therethrough. For example, with the refractive fluid being a liquid, the contaminating fluid could be a gas, such as air. Air bubbles have different optical properties than the refractive liquid, thereby causing optical aberrations to occur in the lens. Air can enter a lens in a variety of ways. For example, air can enter during the assembly of the lens.

SUMMARY OF THE INVENTION

Therefore, it is an object of the present invention to provide a fluid pressure variable lens wherein the edge deformation of a lens element is minimized.

It is a further object of the present invention to provide fluid pressure variable lens eyewear capable of providing a continuum of focal powers that have a large field of view unimpeded by optical aberrations.

It is a further object of the present invention to provide a flexible membrane having a non-flat cross-sectional thickness profile in order to provide a more spherical lens.

It is a further object of the present invention to provide a mechanism for removing contaminating fluid, such as air, from the interior of a fluid filled lens without disassembling the lens.

The present invention provides a lens cell that includes two transparent membranes, with each of said membranes having an edge portion that extends around a periphery of the respective membrane. Each of the edge portions has an interior portion and an exterior portion. At least one of the membranes is flexible. There is a ring located between the interior portions of the edge portions of the membranes. The ring extends around the peripheries of the membranes such that the membranes are spaced apart and form a cavity therebetween. The cavity is filled with a transparent fluid. There is a frame that has a channel located therein. The membrane edge portions are located within the channel. The channel has a lip that is adjacent to the exterior portion of the flexible membrane edge portion. The lip has an inside surface that is spaced apart from an end surface of the ring so as to form a gap. The edge portion of the flexible membrane is clamped between the lip inside surface and the ring end surface, wherein the edge portion of the flexible membrane pivots freely between the lip and ring as the flexible membrane flexes due to changes in the fluid volume in the cavity.