MULTIFOCAL PHASE PLATE WITH A PURE REFRACTIVE PORTION

RELATED APPLICATIONS

This application is related to the following commonly assigned applications, filed on even date herewith: Ser. Nos. 120,262 and 120,263 now abandoned.

BRIEF DESCRIPTION OF THE INVENTION

An ophthalmic contact lens with a phase plate and a pure refractive portion within its optic zone.

BACKGROUND TO THE INVENTION

This invention relates to an improvement in contact lenses and intraocular lenses possessing phase plate optics. A "phase plate", as employed herein and in the claims, is a unitary optical region of a lens utilizing the combination of a zone plate and optical facets in the zones said combination diffracts light to produce a specific wavefront which results in a specific intensity distribution of light at the various order (e.g., 0^{th}, 1^{st}, etc.) foci of the zone plate.

This invention concerns contact lenses, and more particularly contact lenses utilizing phase plate optics, such as phase plate bifocals and "tuned" Fresnel lenses making use of concentric annular zones. Such lenses generally follow the designs described, for example, by Allen L. Cohen in U.S. Pat. Nos. 4,210,391; 4,338,005; and 4,340,283. The lens design of Cohen, supra, provides that the radii "r" of the annular and concentric zones are substantially proportional to $\sqrt{n}$ and that the zones are cut so as to direct light to more than one focal point (herein called a "Cohen lens design").

The Cohen lens design with phase plate optics allows lens constructions which are exceptionally thin. Contact lenses may be designed with phase plate optics in order to achieve a bifocal or multifocal effect. The specific chromatic properties of a phase plate may be incorporated in the design of a contact lens including a contact lens having multifocal properties.

It has been determined that contact lenses with phase plate optics can generate some problems for the wearer. One is the glare that can result from the non-optical edges of the steps between the annularly arranged eshelettes that make up a phase plate and appears through wave interference as a disconcerting, intense light to the contact lens user.

Another potential problem stems from (i) the need in soft contact lenses to have sufficient mobility in the lens' fit to the cornea to allow tear fluid exchange to cleanse the surface of the eye of metabolic waste and (ii) the inability of the soft lens to move sufficiently during wearing to satisfy that needed mobility.

The provision of a multiplicity of multifocal Fresnel eshelettes in the annular zone plate arrangement of the Cohen lens design in a soft contact lens tends to limit the mobility of the lens. It would be desirable to incorporate into the design of such lenses sufficient mobility that the lens has the capacity of moving about 0.5 to about 1 millimeter of distance during wearing. This would enhance the lens' ability to allow management of the buildup of metabolic waste under the lens.

It is the intent of this invention, amongst other things, to provide a multifocal contact lens design encompassed within the annular arrangement of the Cohen patents, supra, which minimizes the effects of glare from the non-optical edges and/or possesses the requisite mobility during use, as characterized above. The invention achieves these results and affects the multifocal utility of a lens with the aforementioned annular arrangement.

THE INVENTION

This invention is directed to an ophthalmic lens such as a contact or intraocular lens, with a phase plate and a pure refractive portion within its optic zone.

More particularly, this invention is directed to an ophthalmic contact lens of the Cohen lens design with a phase plate and a pure refractive portion within its optic zone.

The term "pure refractive portion", as used herein and in the claims, means one or more areas of the lens which operate in accordance with the Fundamental Laws of Geometrical Optics, see Fincham et al., Optics, 9th Ed., page 22[1]. These lens areas are typified by smooth or relatively smooth anterior and posterior surfaces. Hereinafter, the pure refractive portion may be referred to as a "channel", "pure refractive channel" and "phase channel."

1. "Geometrical optics, ignoring diffraction effects due to the wave nature of light, assumes:
(1) Neighbouring rays of light are independent of one another.
(2) The propagation of light is rectilinear, i.e., light travels in straight lines.
(3) Law of reflection.
(4) Law of refraction."

In a preferred embodiment of the invention, the pure refractive portion contributes to a focal power of the phase plate.

In a further embodiment, this invention is directed to a multifocal lens of the Cohen lens design containing a phase plate and a pure refractive portion which symmetrically retards the light passing therethrough (hereinafter termed for convenience "symmetrical channel").

The symmetrical channel diffracts light to constructively interfere with the light waves of the phase zone plate(s) to form or enhance an image at a desired focal point. The symmetrical channel may be regarded as providing essentially monofocal capabilities.

In a preferred embodiment, the phase plate portion is located centrally and the pure refractive portion forms the remaining peripheral annular portion of the optic zone. In a more preferred embodiment of the invention, the pure refractive portion is displaced from the base curve of the lens so as to form a pure refractive channel. In the more preferred embodiment, the pure refractive channel is designed to parallel the base curve of the contact lens and focuses light at the zeroth (0^{th}) diffractive focal point of the phase plate portion of the optic zone.

In the most preferred embodiment of the invention, the phase plate occupies the central portion of the optic zone and the phase plate is designed with half-wave eshelettes so as to split light equally between the zeroth (0^{th}) and first 1^{st}) order diffractive focal points. This is a convenient way to employ the Cohen lens design by providing each plate zone with multifocal capacity and relying on a plurality of them in conjunction with wave interference to achieve multi-focalization. In the most favorable aspect of the most preferred embodiment, the pure refractive channel is located peripherally of the phase plate and set at a quarter-wave depth below the base curve.