OPHTHALMIC LENSES WITH DIFFRACTIVE POWER

RELATED APPLICATIONS

This application is a continuation-in-part of my previous U.S. Applications: Ser. No. 543,257 filed Oct. 19, 1983, now U.S. Pat. No. 4,637,697, entitled "Multifocal Contact Lenses Utilizing Diffraction and Refraction"; Ser. No. 533,993 filed Sept. 20, 1983, now U.S. Pat. No. 4,641,934, entitled "Ophthalmic Lens with Diffractive Power"; and Ser. No. 368,362 filed Apr. 14, 1982, now U.S. Pat. No. 4,642,112, entitled "Artificial Eye Lens".

BACKGROUND OF THE INVENTION

This invention concerns improvements in or relating to ophthalmic lenses, including in particular contact lenses and spectacle lenses.

The human eye is known to exhibit longitudinal chromatic aberration so that objects at the same distance but of different colours cannot all be sharply focussed at the same time. Thus, to effect simultaneous sharp focussing orange and red objects need to be placed farther away than a green object while blue and violet objects have to be nearer the eye than the green object. The extent of the effect is about one dioptre and there is evidence to suggest that the eye/brain system makes use of this to avoid refocussing, concentrating on the blue components of objects that are close and on the red components for distant vision.

SUMMARY OF THE INVENTION

According to the present invention there is provided an ophthalmic lens having positive diffractive power which introduces negative longitudinal chromatic aberration to an extent that more than counteracts the natural positive longitudinal chromatic aberration of the eye so as to provide in use a residual negative longitudinal chromatic aberration. This can enable the eye/brain system to perform a variety of tasks without need to adjust the eye focus (accommodate) by concentrating on the appropriate colour component at the different respective distances.

The designation of the natural longitudinal chromatic aberration as positive is a matter of convention. The opposite convention is also used by some optical designers. Most materials show higher refractive index for blue light and for a positive lens the uncorrected condition gives more positive power for blue light. The terms undercorrect and overcorrect are also used. However, throughout this specification the natural longitudinal chromatic aberration of the eye is called positive and the reverse of this negative.

Preferably the positive diffractive power is of a magnitude such that the introduced negative longitudinal chromatic aberration has an absolute value greater than twice that of the natural positive longitudinal chromatic aberration of the eye, whereby the extent of the residual negative chromatic effect is greater than that of the natural positive chromatic effect. If the extent of negative longitudinal chromatic aberration required to be introduced by the ophthalmic lens is $-D$ dioptres, then the diffractive power of the lens is preferably about $+3.4D$ dioptres (-3.4 being the effective dispersion or V value of diffractive optics); thus if the required extent of the introduced aberration is at least—2 dioptres (to give, with the eye's natural extent of $+1$ dioptre, a residual effect of at least -1 dioptre), then the diffractive power of the lens may be at least $+6.8$ dioptres.

A lens with positive diffractive power providing negative longitudinal chromatic aberration which more than compensates the eye's natural chromatic effect can be advantageous over a lens having negative diffractive power providing positive longitudinal chromatic aberration which adds to the eye's natural chromatic effect for the following reason. A lens with negative diffractive power requires compensating positive refracting power if the residual power is to be zero, and requires a high value of positive refractive power that more than counteracts the negative diffractive power if the patient needs the lens to have residual positive power for corrective purposes. For example, if the diffractive power is about -6 dioptres, the design of lens for a $+12$ dioptres aphakic patient would require about $+18$ dioptres of refractive power. A lens shaped to provide such high positive refractive power requires a large central thickness with all the attendant problems; particularly with a contact lens, discomfort for the wearer and, where relevant, low oxygen transmission. With a lens having positive diffractive power in accordance with the present invention, the refractive power if any, can be relatively low. For example, with diffractive power of about $+8$ dioptres, the design of lens for the $+12$ dioptres aphakic patient requires only $+4$ dioptres of refractive power, and the lens can be relatively thin.

An ophthalmic lens in accordance with the invention need not necessarily have any refractive power, and in particular the refractive power may be zero when the positive diffractive power has a value which equals that required by the patient for corrective purposes. However, a lens in accordance with the invention may have refractive power so that the overall, or residual, power of the lens is determined by the algebraic sum of the diffractive and refractive powers. If desired, the refractive power may be negative and of a magnitude such as to balance, or cancel, the diffractive power so that the overall or residual power is substantially zero. Alternatively, however, the relative values of the diffractive and refractive powers may be such as to provide the lens with an overall or residual power, for example to give the required corrective power for the particular eye with which the ophthalmic lens is to be used. Thus, the refractive power may be negative and of greater magnitude than the diffractive power to give a negative residual power, or may be negative but of smaller magnitude than the diffractive power to give a positive residual power, or may be positive to give a greater positive overall power.

The refractive power is preferably provided by faces which are curved as viewed in axial-section, and which may be of spherical curvature.

The diffractive power is preferably provided by a transmission hologram. The hologram may be optically generated in a surface layer of the lens or within the bulk material of the lens, or may be mechanically generated as a surface relief hologram on the lens or within the lens. The diffractive power may be provided over the full visually used area of the lens, or may be provided over part only of that area. The lens may be a contact lens which may have the diffractive power over its full visually used area. Alternatively, the lens may be a spectacle lens which may have the diffractive power over part only of the visually used area, e.g. over a part corresponding to the near or reading portion of a bifocal or progressive spectacle lens. As a further possibility