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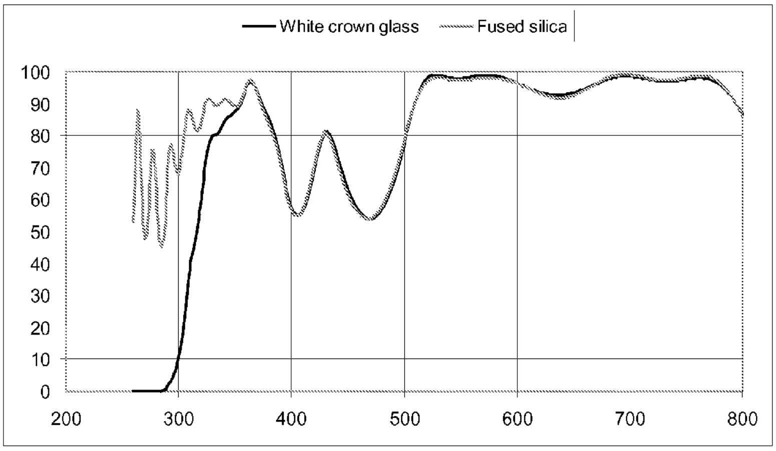

FIG. 1

(57) Abstract: Provided are optical filters and methods for reducing glare from glare-producing light. The optical filters include an optical substrate, and a coating on at least a portion of a surface of the optical substrate. The optical filter may be configured to have an absorption spectrum that is correlated to the emission spectrum of the glare-producing light source. The optical filter may be configured to have a multimodal, such as a bimodal, absorption spectrum for reducing glare from glare-producing light. Also provided are devices and methods for using in the optical filters.

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OPTICAL FILTERS AND METHODS FOR REDUCING GLARE FROM GLARE-PRODUCING LIGHT

INTRODUCTION

Glare from lights can be visually disabling. For example, glare from headlights can be visually disabling to drivers, especially in older drivers. Newer high intensity discharge (HID) headlights are particularly troublesome for drivers because they are brighter than traditional tungsten headlights and have shorter wavelength light, giving them a blue tint. HID lights do not contain a filament, but initially emit light by high voltage excitation of xenon gas, followed by an electrical arc of vaporized metallic salts. Light emitting diodes (LED) are also a recently introduced headlight source that can have greater intensity and shorter wavelength light than their tungsten counterparts. Because short wavelength light undergoes significantly more Rayleigh scattering by the ocular media (e.g., cornea, lens, vitreous), the greater intensity and blue content of the HID and LED headlights can be considerably more deleterious to visual function. In addition, glare from other light sources, such as metal-halide lights can also be visually disabling to people performing activities (e.g., sporting activities) where such lights are frequently used, such as in stadiums or arenas.

There are two types of glare from bright lights: disability glare and discomfort glare. Disability glare results from scattering of light by the ocular media that causes loss of contrast sensitivity. Light scattering within the eye is called straylight, which produces a veil of diffuse illumination over the macula that reduces image contrast. Discomfort glare is a sensation of annoyance and/or actual discomfort when looking at a bright light source. Discomfort glare is aggravated by bright light sources, particularly if they contain a significant short wavelength component. Discomfort glare does not diminish visual function, but can cause ocular fatigue and aversion of gaze. Photostress is a visual disability caused by a glare-producing light source in which foveal sensitivity is reduced, producing a relative scotoma. As dark adaptation occurs, foveal sensitivity is gradually regained. An abnormally slow return of threshold foveal sensitivity after a bright light exposure is seen in macular disease, such as macular degeneration.

SUMMARY

Provided are optical filters and methods for reducing glare from glare-producing light. The optical filters include an optical substrate, and a coating on at least a portion of a surface of the optical substrate. The optical filter may be configured to have an absorption spectrum that is correlated to the emission spectrum of the glare-producing light source. The optical filter may be configured to have a multimodal, such as a bimodal, absorption spectrum for reducing glare from glare-producing light. Also provided are devices and methods for using in the optical filters.

Embodiments of the present disclosure include an optical filter that includes an optical substrate and a coating on at least a portion of a surface of the optical substrate, where the optical filter is configured to have a multimodal absorption spectrum for glare-producing light.

In some embodiments, the optical filter is configured to have a bimodal absorption spectrum for glare-producing light.

In some embodiments of the optical filter, the absorption spectrum of the optical filter is correlated to an emission spectrum of the glare-producing light.

In some embodiments of the optical filter, the coating has an average light transmittance of 40% to 65% from 400 nm to 420 nm and an average light transmittance of 40% to 65% from 440 nm to 470 nm.

In some embodiments, the coating has an average light transmittance of 40% to 65% from 480 nm to 495 nm.

In some embodiments of the optical filter, the coating comprises a first coating and a second coating on the first coating.

In some embodiments of the optical filter, the coating has an average light transmittance of 70% or more from 420 nm to 440 nm.

In some embodiments, the coating has an average light transmittance of 90% or more at wavelengths of 500 nm or greater.

In some embodiments of the optical filter, the coating comprises a metal oxide.

In some embodiments of the optical filter, the coating covers 85% or less of the surfaces of the optical substrate.

In some embodiments of the optical filter, the coating has a decreasing gradient-thickness.

In some embodiments of the optical filter, the optical substrate is a lens, a window or a cover for a lens or a window. In some embodiments, the optical substrate is a lens for spectacles, contact lenses, intraocular lenses, clip-on glasses, fitovers, or goggles, or a headlight lens or cover. In some embodiments, the window is an automotive windshield.

In some embodiments of the optical filter, the glare-producing light is from a glare-producing light source, such as a high-intensity discharge headlight, a light-emitting diode headlight, or a metal-halide light.

In some embodiments, the optical filter is configured to reduce glare from a glare-producing light source without significantly decreasing visual function in a subject.

Embodiments of the present disclosure include an article of eyewear that includes a lens and a coating on at least a portion of a surface of the lens, where the article of eyewear is configured to have a multimodal absorption spectrum for glare-producing light.

In some embodiments, the article of eyewear is configured to have a bimodal absorption spectrum for glare-producing light.

In some embodiments of the article of eyewear, the lens is a corrective lens.

In some embodiments of the article of eyewear, the lens is a non-corrective lens.

In some embodiments, the lens is a lens for spectacles, contact lenses, intraocular lenses, clip-on glasses, fitovers, or goggles.

Embodiments of the present disclosure include a method of reducing glare from a glare-producing light source. The method includes positioning an optical filter between the glare-producing light source and a retina of a subject. The optical filter includes an optical substrate and a coating on at least a portion of a surface of the optical substrate, where the optical filter is configured to have an absorption spectrum that is correlated to the emission spectrum of the glare-producing light source at wavelengths of 500 nm or less.

In some embodiments, the method further includes selecting the optical filter such that the optical filter is configured to have an absorption spectrum that is correlated to the emission spectrum of the glare-producing light source at wavelengths of 500 nm or less.

In some embodiments, the optical filter is configured to have a multimodal absorption spectrum for glare-producing light from the glare-producing light source.

In some embodiments of the method, the optical filter is configured to have a bimodal absorption spectrum for glare-producing light from the glare-producing light source.

In some embodiments, the optical filter has an optical density such that the optical filter is configured to reduce glare from the glare-producing light source without causing a significant decrease in visual function.

In some embodiments, the optical filter has an optical density such that the optical filter is configured to reduce glare from the glare-producing light source without causing a significant decrease in visual function in conditions of reduced illumination.

In some embodiments of the method, the subject has been diagnosed with age-related macular degeneration.

In some embodiments of the method, the glare-producing light source is a high-intensity discharge headlight, a light-emitting diode headlight, or a metal-halide light.

In some embodiments, the optical filter is configured to reduce glare from the glare-producing light source in left-sided oncoming traffic.

Embodiments of the present disclosure include a method of producing an optical filter. The method includes coating at least a portion of a surface of an optical substrate with a coating configured to have an absorption spectrum that is correlated to the emission spectrum of a glare-producing light source at wavelengths of 500 nm or less.

In some embodiments, the optical filter is configured to have a bimodal absorption spectrum for glare-producing light to produce an optical filter.

In some embodiments, the contacting includes directing an evaporated metal and an ion source towards the surface of the optical substrate.

In some embodiments, the method further includes cooling the optical substrate.

BRIEF DESCRIPTION OF THE FIGURES

FIG. 1 shows a graph of transmittance (%) vs. wavelength (nm) for an optical filter coated onto white crown glass and fused silica according to embodiments of the present disclosure.

FIG. 2 shows a graph of transmittance (%) vs. wavelength (nm) for an optical filter according to embodiments of the present disclosure.

FIG. 3 shows a graph of transmittance (%) vs. wavelength (nm) for an optical filter according to embodiments of the present disclosure.

FIG. 4 shows a drawing of an optical filter with a decreasing gradient-thickness coating according to embodiments of the present disclosure.

FIG. 5 shows a graph of percent glare discomfort in subjects for an optical filter vs. a blank (e.g., no filter) according to embodiments of the present disclosure.

FIG. 6 shows a graph of percent subjects experiencing photophobia for an optical filter vs. a blank (e.g., no filter) according to embodiments of the present disclosure.

FIG. 7 shows a graph of percent reduction in foveal sensitivity in subjects for an optical filter vs. a blank (e.g., no filter) according to embodiments of the present disclosure.

FIG. 8 shows a graph of percent glare discomfort in subjects for an optical filter vs. plano spectacles with an anti-reflective coating (ARC) according to embodiments of the present disclosure.

FIG. 9 shows a graph of contrast sensitivity (log) in subjects for an optical filter vs. a blank (e.g., no filter) according to embodiments of the present disclosure.

FIG. 10 shows a graph of foveal sensitivity in subjects for an optical filter vs. a blank (e.g., no filter) according to embodiments of the present disclosure.

FIG. 11 shows a graph of parafoveal sensitivity in subjects for an optical filter vs. a blank (e.g., no filter) according to embodiments of the present disclosure.

FIG. 12 shows graphs of the spectral power distribution (relative power vs. wavelength (nm)) for five examples of HID light sources.

FIG. 13 shows a graph of radiant intensity (W/sr nm) vs. wavelength (nm) for an example of a LED light source.

FIG. 14 shows a graph of the spectral power distribution of a metal-halide stadium light. Shaded vertical bars overly peaks of blue light intensity that are filtered to reduce glare according to embodiments of the present disclosure.

FIG. 15 shows a graph of percent transmittance vs. wavelength (nm) for the subject optical filters according to embodiments of the present disclosure.

Before the present invention is described in greater detail, it is to be understood that this invention is not limited to the particular embodiments described, and as such may, of course, vary. It is also to be understood that the terminology used herein is for the purpose of describing particular embodiments only, and is not intended to be limiting, since the scope of the present invention is embodied by the appended claims.

Where a range of values is provided, it is understood that each intervening value, to the tenth of the unit of the lower limit unless the context clearly dictates otherwise, between the upper and lower limit of that range and any other stated or intervening value in that stated range, is encompassed within the invention. The upper and lower limits of these smaller ranges may independently be included in the smaller ranges and are also encompassed within the invention, subject to any specifically excluded limit in the stated range. Where the stated range includes one or both of the limits, ranges excluding either or both of those included limits are also included in the invention.

Unless defined otherwise, all technical and scientific terms used herein have the same meaning as commonly understood by one of ordinary skill in the art to which this invention belongs. Although any methods and materials similar or equivalent to those described herein can also be used in the practice or testing of the present invention, representative illustrative methods and materials are now described.

It is noted that, as used herein and in the appended claims, the singular forms “a”, “an”, and “the” include plural referents unless the context clearly dictates otherwise. It is further noted that the claims may be drafted to exclude any optional element. As such, this statement is intended to serve as antecedent basis for use of such exclusive terminology as “solely,” “only” and the like in connection with the recitation of claim elements, or use of a “negative” limitation.

As will be apparent to those of skill in the art upon reading this disclosure, each of the individual embodiments described and illustrated herein has discrete components and features which may be readily separated from or combined with the features of any of the other several embodiments without departing from the scope or spirit of the present invention. In addition, it will be readily apparent to one of ordinary skill in the art in light of the teachings herein that certain changes and modifications may be made thereto without departing from the spirit and scope of the appended claims. Any recited method can be carried out in the order of events recited or in any other order which is logically possible.

All publications and patents cited in this specification are herein incorporated by reference as if each individual publication or patent were specifically and individually indicated to be incorporated by reference and are incorporated herein by reference to disclose and describe the methods and/or materials in connection with which the publications are cited. To the extent such publications may set out definitions of a term that conflicts with the explicit or implicit definition of the present disclosure, the definition of the present disclosure controls. The citation of any publication is for its disclosure prior to the filing date and should not be construed as an admission that the present invention is not entitled to antedate such publication by virtue of prior invention. Further, the dates of publication provided may be different from the actual publication dates which may need to be independently confirmed.

DETAILED DESCRIPTION

Provided are optical filters and methods for reducing glare from glare-producing light. The optical filters include an optical substrate, and a coating on at least a portion of a surface of the optical substrate. The optical filter may be configured to have an absorption spectrum that is correlated to the emission spectrum of the glare-producing light source. The optical filter may be configured to have a multimodal, such as a bimodal, absorption spectrum for reducing glare from glare-producing light. In some cases, the optical filter is configured to reduce glare from glare-producing light without a significant decrease in a subject's visual function. For instance, the optical filter may be configured to reduce discomfort glare from glare-producing light without a significant decrease in a subject's visual acuity, contrast sensitivity, foveal sensitivity and/or parafoveal sensitivity. Also provided are devices and methods for using in the optical filters.

Embodiments of the present disclosure may include an optical filter configured to reduce discomfort glare from glare-producing light and substantially transmit light at wavelengths other than the wavelengths for the glare-producing light. For example, the optical filter may be configured to reduce discomfort glare from glare-producing light and substantially transmit light at longer wavelengths than the glare-producing light. In some cases, the optical filter is configured to reduce discomfort glare from glare-producing light without a significant decrease in a subject's visual function. For instance, the optical filter may be configured to reduce discomfort glare from glare-producing light without a significant decrease in a subject's visual acuity, contrast sensitivity, foveal sensitivity or parafoveal sensitivity.

Below, the optical filters are described first in greater detail, followed by a review of the devices and methods in which the optical filters find use, as well as a discussion of various representative applications in which the optical filters, devices and methods find use.

OPTICAL FILTERS

Embodiments of the present disclosure include an optical filter configured to reduce glare from a light source. Glare is caused by light entering the eye that does not aid vision, typically environmental luminance, such as headlight or streetlight exposures that are too intense across the visual field. In some cases, reducing glare includes reducing the occurrence of glare perceived by a subject exposed to a light source. For example, reducing glare may include decreasing the severity and/or incidence of glare perceived by a subject, or a group of subjects, exposed to a light source. In some instances, the optical filter is configured to reduce discomfort glare in a subject exposed to a light source. "Discomfort glare" as used herein refers to glare that causes annoyance. Discomfort glare is a response to abnormal illumination and may occur as annoyance, squinting, distraction, blinking, tearing or light aversion. In some cases, the optical filter is configured to reduce photophobia in a subject exposed to a light source. "Photophobia" as used herein refers to an abnormal response (e.g., pain) to illumination by an offending light. In some cases, reducing photophobia includes reducing the occurrence of photophobia in a subject exposed to a light source. For example, reducing photophobia may include decreasing the severity and/or incidence of photophobia in a subject, or a group of subjects, exposed to a light source.

In certain embodiments, the light source is a glare-producing light source. A glare-producing light source may have intensity sufficient to produce the perception of glare in a subject. In some cases, the light source is a discomfort glare-inducing light source. A discomfort glare-inducing light source may have intensity sufficient to cause discomfort glare in a subject. In some instances, the glare-producing light source is an artificial light source, such as, but not limited to, an automotive headlight, a streetlight, a stadium light, a flashlight, and the like. For example, the glare-producing light source may be an automotive headlight, such as a high-intensity discharge (HID) headlight or a light-emitting diode (LED) headlight. In some cases, the glare-producing light source may be a metal-halide light, such as a stadium light.

In certain embodiments, the optical filter is selected to have an absorption spectrum that is correlated to the emission spectrum of the glare-producing light source. For example, the optical filter may be selected to have an absorption spectrum that is correlated to the emission spectrum of the glare-producing light source at wavelengths of 500 nm or less.

In certain embodiments, the optical filter is configured to have a multimodal absorption spectrum. By "multimodal" is meant that there are two or more (e.g., 2 or more, 3 or more, 4 or more, 5 or more, etc., such a 2 to 10, or 2 to 8, or 2 to 6, or 2 to 4) distinct peaks (e.g., local maxima) in the absorption spectrum of the optical filter. Stated another way, an optical filter may have a multimodal transmission spectrum, where there are two or more (e.g., 2 or more, 3 or more, 4 or more, 5 or more, etc., such a 2 to 10, or 2 to 8, or 2 to 6, or 2 to 4) distinct valleys (e.g., local minima) in the transmission spectrum of the optical filter. For instance, the optical filter may have a multimodal absorption spectrum in the wavelength range of glare-producing light (e.g., wavelengths of 500 nm or less). In certain cases, the optical filter is configured to have a bimodal absorption spectrum. By "bimodal" is meant that there are two distinct peaks (e.g., local maxima) in the absorption spectrum. Stated another way, an optical filter may have a bimodal transmission spectrum, where there are two distinct valleys (e.g., local minima) in the transmission spectrum of the optical filter. For instance, the optical filter may have a bimodal absorption spectrum in the wavelength range of glare-producing light (e.g., wavelengths of 500 nm or less). By "peak" or "distinct peak" is meant a curve in the absorption spectrum where the difference between the percent absorbance at the vertex of the curve and the percent absorbance at an inflection point of the curve is 10% or more. Similarly, a "valley" or "distinct valley" in a transmission spectrum occurs where the difference between the percent transmittance at the vertex of the curve and the percent transmittance at an inflection point of the curve is 10% or more. In certain embodiments, the absorbance (i.e., optical density) of a material is a logarithmic ratio of the incident light, to the light transmitted through the material. Conversely, the percent transmittance of a material is the percentage of incident light at a certain wavelength that passes through the material.

In certain embodiments, the optical filter is configured such that the absorption spectrum of the optical filter is correlated to an emission spectrum of a light source (e.g., a glare-producing light source, such as a HID headlight, a LED headlight, both HID and LED headlights, or a metal-halide light, such as a stadium light). By "correlated" is meant that the absorption spectrum of the optical filter may have one or more local maxima at substantially the same wavelength(s) as one or more local maxima in the emission spectrum of a glare-producing light over a desired range of wavelengths.

In some cases, the glare-producing light source has one or more local maxima in its emission spectrum. For example, the glare-producing light may have a local maximum at a certain wavelength. In some cases, the glare-producing light may have local maxima at two or more distinct wavelengths. In certain instances, the glare-producing light has a first local maximum at a wavelength ranging from 380 nm to 440 nm, such as from 390 nm to 430 nm, including from 400 nm to 420 nm. For instance, the glare-producing light may have a local maximum at a wavelength ranging from 400 nm to 420 nm. In some embodiments, the glare-producing light has a second local maximum at a wavelength ranging from 420 nm to 500 nm, such as from 430 nm to 490 nm, or from 430 nm to 480 nm, including from 440 nm to 470 nm, or from 450 to 470 nm. For instance, the glare-producing light may have a second local maximum at a wavelength ranging from 440 nm to 470 nm, or from 450 nm to 470 nm. In some embodiments, the glare-producing light has a third local maximum at a wavelength ranging from 450 nm to 500 nm, such as 455 nm to 500 nm, or from 460 nm to 500 nm, or from 465 nm to 500 nm, or from 470 nm to 500 nm, or from 475 nm to 500 nm, or from 475 nm to 495 nm, or from 480 nm to 495 nm, or from 485 nm to 495 nm. For instance, the glare-producing light may have a third local maximum at a wavelength ranging from 480 nm to 495 nm. For example, a metal-halide light may have an emission spectrum with a first local maximum at a wavelength ranging from 400 nm to 420 nm, a second local maximum at a wavelength ranging from 450 nm to 470 nm, and a third local maximum at a wavelength ranging from 480 nm to 495 nm. FIG. 12 shows graphs of the spectral power distribution (relative power vs. wavelength (nm)) for five examples of HID headlights. In other examples, a LED headlight may have an emission spectrum with a local maximum at a wavelength ranging from 440 nm to 460 nm. FIG. 13 shows a graph of radiant intensity (W/sr nm) vs. wavelength (nm) for an example of a LED light source. FIG. 14 shows a graph of the spectral power distribution of a metal-halide stadium light.

In certain embodiments, the optical filter is configured such that the absorption spectrum of the optical filter is correlated to an emission spectrum of the glare-producing light. The optical filter may be configured such that the absorption spectrum of the optical filter has a multimodal (e.g., bimodal) distribution where one or more of the local maxima of the absorption spectrum of the optical filter are at substantially the same wavelength as the local maxima of the emission spectrum of the glare-producing light. For example, the optical filter may be configured such that the absorption spectrum of the optical filter has a local maximum at substantially the same wavelength as a local maximum in the emission spectrum of the glare-producing light.

In some cases, the optical filter may be configured such that the absorption spectrum of the optical filter has a first local maximum at substantially the same wavelength as a first local maximum in the emission spectrum of the glare-producing light, and a second local maximum at substantially the same wavelength as a second local maximum in the emission spectrum of the glare-producing light. Stated another way, the optical filter may be configured such that the percent transmittance of the optical filter is correlated to an emission spectrum of the glare-producing light. The optical filter may be configured such that the percent transmittance of the optical filter has a multimodal (e.g., bimodal) distribution where one or more of the local minima in the percent transmittance of the optical filter are at substantially the same wavelength as the local maxima of the emission spectrum of the glare-producing light. For example, the optical filter may be configured such that the percent transmittance of the optical filter has a local minimum at substantially the same wavelength as a local maximum in the emission spectrum of the glare-producing light. In some cases, the optical filter may be configured such that the percent transmittance of the optical filter has a first local minimum at substantially the same wavelength as a first local maximum in the emission spectrum of the glare-producing light, and a second local minimum at substantially the same wavelength as a second local maximum in the emission spectrum of the glare-producing light.

For example, embodiments of the optical filter are configured to have an average light transmittance of 90% or less at a wavelength ranging from 400 nm to 420 nm, such as an average light transmittance of 85% or less, including 80% or less, or 75% or less, or 70% or less, or 65% or less, or 60% or less, or 55% or less, or 50% or less, or 45% or less, or 40% or less, or 35% or less, or 30% or less, or 25% or less at a wavelength ranging from 400 nm to 420 nm. Other ranges of wavelengths correlated to the emission spectra of glare-producing light (e.g., HID, LED, both HID and LED light sources, or a metal-halide light source, such as a stadium light) are also possible, such as, but not limited to, wavelengths ranging from 380 nm to 440 nm, such as from 385 nm to 435 nm, or from 390 nm to 430 nm, including from 395 nm to 425 nm, or from 400 nm to 420 nm.

In some cases, the optical filter is configured to have an average light transmittance of 90% or less at a wavelength ranging from 440 nm to 470 nm, such as an average light transmittance of 85% or less, including 80% or less, or 75% or less, or 70% or less, or 65% or less, or 60% or less, or 55% or less, or 50% or less, or 45% or less, or 40% or less, or 35% or less, or 30% or less, or 25% or less at a wavelength ranging from 440 nm to 470 nm. Other ranges of wavelengths correlated to the emission spectra of glare-producing light (e.g., HID, LED, both HID and LED light sources, or a metal-halide light source, such as a stadium light) are also possible, such as, but not limited to, wavelengths ranging from 420 nm to 500 nm, or from 425 nm to 495 nm, or from 430 nm to 490 nm, or from 430 nm to 485 nm, or from 430 nm to 480 nm, or from 435 nm to 475 nm, including from 440 nm to 470 nm, or from 445 nm to 470 nm, or from 450 to 470 nm. In addition, in certain embodiments, ranges of wavelengths correlated to the emission spectra of glare-producing light include wavelengths ranging from 450 nm to 500 nm, such as 455 nm to 500 nm, or from 460 nm to 500 nm, or from 465 nm to

500 nm, or from 470 nm to 500 nm, or from 475 nm to 500 nm, or from 475 nm to 495 nm, or from 480 nm to 495 nm, or from 485 nm to 495 nm.

In certain instances, the optical filter is configured to have both an average light transmittance of 90% or less at a wavelength ranging from 400 nm to 420 nm, such as an average light transmittance of 85% or less, including 80% or less, or 75% or less, or 70% or less, or 65% or less, or 60% or less, or 55% or less, or 50% or less, or 45% or less, or 40% or less, or 35% or less, or 30% or less, or 25% or less at a wavelength ranging from 400 nm to 420 nm, and an average light transmittance of 90% or less at a wavelength ranging from 440 nm to 470 nm, such as an average light transmittance of 85% or less, including 80% or less, or 75% or less, or 70% or less, or 65% or less, or 60% or less, or 55% or less, or 50% or less, or 45% or less, or 40% or less, or 35% or less, or 30% or less, or 25% or less at a wavelength ranging from 440 nm to 470 nm. Other ranges of wavelengths correlated to the emission spectra of glare-producing light (e.g., HID, LED, both HID and LED light sources, or a metal-halide light source, such as a stadium light) are also possible, such as, but not limited to, wavelengths ranging from 380 nm to 440 nm, or from 385 nm to 435 nm, such as from 390 nm to 430 nm, or from 395 nm to 425 nm, including from 400 nm to 420 nm, and wavelengths ranging from 420 nm to 500 nm, or from 425 nm to 495 nm, or from 430 nm to 490 nm, or from 430 nm to 485 nm, or from 430 nm to 480 nm, or from 435 nm to 475 nm, including from 440 nm to 470 nm, or from 445 nm to 470 nm, or from 450 to 470 nm, and wavelengths ranging from 450 nm to 500 nm, such as 455 nm to 500 nm, or from 460 nm to 500 nm, or from 465 nm to 500 nm, or from 470 nm to 500 nm, or from 475 nm to 500 nm, or from 475 nm to 495 nm, or from 480 nm to 495 nm, or from 485 nm to 495 nm.

In some cases, the optical filter is configured to have an average light transmittance of 25% to 90% at a wavelength ranging from 400 nm to 420 nm, such as an average light transmittance of 25% to 85%, including 30% to 80%, or 35% to 75%, or 40% to70%, or 40% to 65%, or 45% to 60%, or 50% to 60% to at a wavelength ranging from 400 nm to 420 nm. Other ranges of wavelengths correlated to the emission spectra of glare-producing light (e.g., HID, LED, both HID and LED light sources, or a metal-halide light source, such as a stadium light) are also possible, such as, but not limited to, wavelengths ranging from 380 nm to 440 nm, or from 385 nm to 435 nm, such as from 390 nm to 430 nm, or from 395 nm to 425 nm, including from 400 nm to 420 nm.

In certain instances, the optical filter is configured to have an average light transmittance of 25% to 90% at a wavelength ranging from 440 nm to 470 nm, such as an average light transmittance of 25% to 85%, including 30% to 80%, or 35% to 75%, or 40% to70%, or 40% to 65%, or 45% to 60%, or 50% to 60% to at a wavelength ranging from 440 nm to 470 nm. Other ranges of wavelengths correlated to the emission spectra of glare-producing light (e.g., HID, LED, both HID and LED light sources, or a metal-halide light source, such as a stadium light) are also possible, such as, but not limited to, wavelengths ranging from 420 nm to 500 nm, or from 425 nm to 495 nm, such as from 430 nm to 490 nm, or from 430 nm to 485 nm, or from 430 nm to 480 nm, or from 435 nm to 475 nm, including from 440 nm to 470 nm, or from 445 nm to 470 nm, or from 450 to 470 nm.

In certain embodiments, the optical filter is configured to have both an average light transmittance of 25% to 90% at a wavelength ranging from 400 nm to 420 nm, such as an average light transmittance of 25% to 85%, including 30% to 80%, or 35% to 75%, or 40% to70%, or 40% to 65%, or 45% to 60%, or 50% to 60% to at a wavelength ranging from 400 nm to 420 nm, and an average light transmittance of 25% to 90% at a wavelength ranging from 440 nm to 470 nm, such as an average light transmittance of 25% to 85%, including 30% to 80%, or 35% to 75%, or 40% to70%, or 40% to 65%, or 45% to 60%, or 50% to 60% to at a wavelength ranging from 440 nm to 470 nm. Other ranges of wavelengths correlated to the emission spectra of glare-producing light (e.g., HID, LED, both HID and LED light sources, or a metal-halide light source, such as a stadium light) are also possible, such as, but not limited to, wavelengths ranging from 380 nm to 440 nm, or from 385 nm to 435 nm, such as from 390 nm to 430 nm, or from 395 nm to 425 nm, including from 400 nm to 420 nm, and wavelengths ranging from 420 nm to 500 nm, or from 425 nm to 495 nm, such as from 430 nm to 490 nm, or from 430 nm to 485 nm, or from 430 nm to 480 nm, or from 435 nm to 475 nm, including from 440 nm to 470 nm, or from 445 nm to 470 nm, or from 450 to 470 nm, and wavelengths ranging from 450 nm to 500 nm, such as 455 nm to 500 nm, or from 460 nm to 500 nm, or from 465 nm to 500 nm, or from 470 nm to 500 nm, or from 475 nm to 500 nm, or from 475 nm to 495 nm, or from 480 nm to 495 nm, or from 485 nm to 495 nm.

Combinations of any of the above ranges of wavelengths are also possible for the optical filters. For example, the optical filter may be configured to have an average light transmittance as described above at wavelengths correlated to the local maxima of glare-producing light as described above, such as one or more of a first local maximum at a wavelength ranging from 380 nm to 440 nm, such as from 390 nm to 430 nm, including from 400 nm to 420 nm (e.g., a first local maximum at a wavelength ranging from 400 nm to 420 nm), a second local maximum at a wavelength ranging from 420 nm to 500 nm, such as from 430 nm to 490 nm, or from 430 nm to 480 nm, including from 440 nm to 470 nm, or from 450 to 470 nm (e.g., a second local maximum at a wavelength ranging from 440 nm to 470 nm, or from 450 nm to 470 nm), and a third local maximum at a wavelength ranging from 450 nm to 500 nm, such as 455 nm to 500 nm, or from 460 nm to 500 nm, or from 465 nm to 500 nm, or from 470 nm to 500 nm, or from

475 nm to 500 nm, or from 475 nm to 495 nm, or from 480 nm to 495 nm, or from 485 nm to 495 nm (e.g., a third local maximum at a wavelength ranging from 480 nm to 495 nm).

In addition to the multimodal (e.g., bimodal) absorption spectrum for glare-producing light described above, the optical filter may also be configured to substantially transmit light at wavelengths other than the ranges of filtered wavelengths described above. In some cases, the optical filter is configured to substantially transmit light at wavelengths between two ranges of wavelengths described above for the optical filter. For example, the optical filter may be configured to have an average light transmittance of 50% or more at a wavelength ranging from 420 nm to 440 nm, such as an average light transmittance of 55% or more, including 60% or more, or 65% or more, or 70% or more, or 75% or more, or 80% or more, or 85% or more, or 90% or more at a wavelength ranging from 420 nm to 440 nm. Other ranges of wavelengths correlated to the emission spectra of glare-producing light (e.g., HID, LED, both HID and LED light sources, or a metal-halide light source, such as a stadium light) are also possible, such as, but not limited to, wavelengths ranging from 410 nm to 450 nm, such as from 415 nm to 445 nm, including from 420 nm to 440 nm, and wavelengths ranging from 460 nm to 500 nm, such as 465 nm to 495 nm, or from 470 nm to 490 nm, or from 475 nm to 485 nm, or from 470 nm to 480 nm.

In some embodiments, the optical filter is configured to reduce glare from glare-producing light while not significantly affecting visual function (e.g., without a significant decrease in a subject's visual acuity, contrast sensitivity, foveal sensitivity or parafoveal sensitivity). For example, the optical filter may be configured to reduce glare from glare-producing light without significantly decreasing one or more of visual acuity, contrast sensitivity, foveal sensitivity, and parafoveal sensitivity. In certain embodiments, the optical filter is configured to reduce glare from glare-producing light without significantly decreasing one or more of visual acuity, contrast sensitivity, foveal sensitivity, and parafoveal sensitivity in conditions of reduced illumination (e.g., dusk, nighttime, early morning, etc.).

For example, the optical filter may be configured to substantially transmit light at wavelengths in the visible spectrum other than the ranges of wavelengths for glare-producing light described above. In some cases, the optical filter is configured to substantially transmit light at wavelengths greater than the multimodal (e.g., bimodal) portion of the absorption spectrum for the optical filter. For instance, the optical filter may be configured to substantially transmit light at wavelengths of 600 nm and greater, or 575 nm and greater, such as 550 nm and greater, including 500 nm and greater, or 490 nm or greater, or 480 nm or greater, or 470 nm or greater. For example, the optical filter may be configured to transmit 60% or more of light at wavelengths of 500 nm or greater, such as 65% or more, including 70% or more, or 75% or more, or 80% or more, or 85% or more, or 90% or more, or 95% or more of light at wavelengths of 500 nm or greater. In certain cases, the optical filter may be configured to transmit 95% or more of light at wavelengths of 500 nm or greater. In some embodiments, an optical filter configured to substantially transmit light in the visible spectrum at wavelengths greater than glare-producing light may facilitate a reduction in glare from glare-producing light while not significantly affecting visual function (e.g., without a significant decrease in a subject's visual acuity, contrast sensitivity, foveal sensitivity or parafoveal sensitivity).

FIG. 1 shows a graph of transmittance (%) vs. wavelength (nm) for an optical filter with a bimodal percent transmittance. As shown in FIG. 1, an optical filter with a coating on white crown glass and an optical filter with a coating on fused silica were tested for transmittance (%) over a range of wavelengths (nm). The transmittance (%) shows a first local minimum at about 410 nm and a second local minimum at about 470 nm.

FIG. 2 shows a graph of transmittance (%) vs. wavelength (nm) for another embodiment of an optical filter with a bimodal percent transmittance. As shown in FIG. 2, the optical filter has a first local minimum in transmittance (%) at about 410 nm and a second local minimum at about 460 nm.

FIG. 3 shows a graph of transmittance (%) vs. wavelength (nm) for another embodiment of an optical filter with a bimodal percent transmittance. As shown in FIG. 3, the optical filter has a first local minimum in transmittance (%) at about 410 nm and a second local minimum at about 460 nm.

Embodiments of the optical filter include an optical substrate. The optical substrate may be any type of optical substrate that is substantially transparent and may be used as a lens, a window, a cover for a lens, a cover for a window, and the like. In some cases, the optical substrate is a lens. The lens may be a lens for an article of eyewear (e.g., an eyewear lens). For example, the eyewear lens may include, but is not limited to a lens for spectacles (e.g., glasses), contact lenses, intraocular lenses, clip-on glasses, fitovers, goggles, and the like. The eyewear lens may be a corrective lens (i.e., a prescription lens) or a non-corrective lens (i.e., a non-prescription lens). In certain instances, the lens is a lens for an automotive headlight (e.g., a headlight lens), or a cover for an automotive headlight. In certain embodiments, the optical substrate is a window, such as, but not limited to, an automotive window, such as an automotive windshield, side windows or rear window. In some cases, the optical substrate is a mirror, such as, but not limited to, an automotive mirror, such as a rear view mirror or side mirrors. In certain instances, the optical substrate includes a substantially transparent material. For example, the optical substrate may be a glass, such as crown glass, fused silica, and the like. In some cases, the optical substrate is a plastic, such as, but not limited to, allyl diglycol carbonate (i.e., CR-39), polycarbonate, and the like.

Embodiments of the optical filter include a coating on a surface of the optical substrate. In certain embodiments, the coating is configured to reduce glare from a glare-producing light and/or reduce photophobia from a photophobia-inducing light, as described above. For example, as described above, the coating may be configured such that the absorption spectrum of the coating is correlated to an emission spectrum of a light source (e.g., a glare-producing light source). The coating may be configured such that the absorption spectrum of the coating has a multimodal (e.g., bimodal) distribution where one or more of the local maxima of the absorption spectrum of the coating are at substantially the same wavelength as the local maxima of the emission spectrum of the glare-producing light. For example, the coating may be configured such that the absorption spectrum of the coating has a local maximum at substantially the same wavelength as a local maximum in the emission spectrum of the glare-producing light. In some cases, the coating may be configured such that the absorption spectrum of the coating has a first local maximum at substantially the same wavelength as a first local maximum in the emission spectrum of the glare-producing light, and a second local maximum at substantially the same wavelength as a second local maximum in the emission spectrum of the glare-producing light.

Stated another way, the coating may be configured such that the percent transmittance of the coating is correlated to an emission spectrum of the glare-producing light. The coating may be configured such that the percent transmittance of the coating has a multimodal distribution where one or more (e.g., 2 or more, 3 or more, 4 or more, etc.) of the local minima in the percent transmittance of the coating are at substantially the same wavelength as the local maxima of the emission spectrum of the glare-producing light (e.g., wavelengths of 500nm or less). For example, the coating may be configured such that the percent transmittance of the coating has a local minimum at substantially the same wavelength as a local maximum in the emission spectrum of the glare-producing light. In some cases, the coating may be configured such that the percent transmittance of the coating has a plurality of local minima at substantially the same wavelengths as corresponding local maxima in the emission spectrum of the glare-producing light. Specific ranges for average light transmittance at various wavelengths for the coating are as described above in relation to the optical filter.

In certain embodiments, the coating is configured such that the percent transmittance of the coating has a bimodal distribution where two of the local minima in the percent transmittance of the coating are at substantially the same wavelengths as two local maxima of the emission spectrum of the glare-producing light. For example, the coating may be configured such that the percent transmittance of the coating has first local minimum at substantially the same wavelength as a first local maximum in the emission spectrum of the glare-producing light, and a second local minimum at substantially the same wavelength as a second local maximum in the emission spectrum of the glare-producing light. Specific ranges for average light transmittance at various wavelengths for the coating are as described above in relation to the optical filter.

In certain embodiments, the coating is a single layer coating. A single layer coating is a coating that is substantially homogeneous. A single layer coating may be applied to the optical substrate in a single application, or via two or more applications of substantially the same coating composition, such that the coating produced is substantially homogeneous (e.g., has substantially the same chemical and/or physical properties). For example, the single layer coating may be configured to reduce glare (e.g., discomfort glare) from a glare-producing light and/or reduce photophobia from a light source, as described above. In these embodiments, the single layer coating may be configured to provide a multimodal (e.g., bimodal) absorption spectrum or a multimodal (e.g., bimodal) percent transmittance as described above. For example, as described above, the single-layer coating may be configured such that one or more local minima in the percent transmittance of the coating are correlated to one or more corresponding local maxima in the emission spectrum of a light source (e.g., a glare-producing light source).

In other embodiments, the coating is a multi-layer coating that includes two or more layers. For instance, the coating may include 2 or more layers, 3 or more layers, 4 or more layers, 5 or more layers, 6 or more layers, 7 or more layers, 8 or more layers, 9 or more layers, or 10 or more layers. In some cases, the coating includes 1 to 10 layers, such as 2 to 10 layers, or 3 to 10 layers, etc. In some cases, the layers of the coating may be on a single side of the optical substrate. For instance, the layers of the coating may be on the side of the optical substrate that is further from the user, such as on a side of a lens distal from the user (e.g., the front side of the lens relative to the user). In other instances, the coating may be on the side of the optical substrate that is nearer to a user, such as on the side of a lens proximal to the user (e.g., the back side of the lens relative to the user). In certain embodiments, the layers of the coating are on more than one side of the optical substrate, such as on two opposing sides of the optical substrate. For instance, the layers of the coating may be on both the proximal and distal sides of a lens (e.g., both the front and back sides of the lens relative to the user).

In certain instances, each layer in the coating has the same chemical and/or physical properties. In other embodiments, the layers in the coating may have different chemical and/or physical properties. For example, different layers in the coating may have different chemical and/or physical properties such that the different layers are configured to have absorption spectra that each correspond to a peak (e.g., local maximum) of an emission spectrum from the same glare-producing light source. In these embodiments, the combined absorption spectra from the layers may correspond to the desired glare-producing portion of the emission spectrum of the glare-producing light source. In other embodiments, the different layers in the coating may have different chemical and/or physical properties such that the different layers are configured to have absorption spectra that each correspond to an emission spectrum, or portion thereof, from a different glare-producing light source.

For example, the coating may include a first layer having a first set of chemical and/or physical properties, and a second layer having a second set of chemical and/or physical properties different from the first set. Each layer may be applied in a single application or in two or more applications, as described above. In some embodiments, the coating may be a multi-layer coating, such as a coating that includes a first layer and a second layer. The multi-layer coating may be configured to provide a multimodal (e.g., bimodal) absorption spectrum or a (multimodal (e.g., bimodal) percent transmittance as described above. For example, the first layer and the second layer may be configured to have a combined absorption spectrum such that a first local minimum in the percent transmittance of the combined layers is correlated to a corresponding first local maximum in the emission spectrum of a light source, and a second local minimum in the percent transmittance of the combined layers is correlated to a corresponding second local maximum in the emission spectrum of a light source. For instance, the coating may include a first coating and a second coating, where the first and second coatings combined have an average light transmittance of 40% to 65% from 400 nm to 420 nm, and an average light transmittance of 40% to 65% from 440 nm to 470 nm. Other possible ranges of percent transmittance and wavelengths are as described above.

In certain embodiments, the coating is on at least a portion of a surface of the optical substrate. In some cases, the coating may be on a single side of the optical substrate. For instance, the coating may be on the side of the optical substrate that is further from the user, such as on a side of a lens distal from the user (e.g., the front side of the lens relative to the user). In other instances, the coating may be on the side of the optical substrate that is nearer to a user, such as on the side of a lens proximal to the user (e.g., the back side of the lens relative to the user).

In certain embodiments, the coating is on more than one side of the optical substrate, such as on two opposing sides of the optical substrate. For instance, the coating may be on both the proximal and distal sides of a lens (e.g., both the front and back sides of the lens relative to the user). In embodiments that have more than one coating, each coating may have the same chemical and/or physical properties. In other embodiments, the coatings may have different chemical and/or physical properties. For example, different coatings may have different chemical and/or physical properties such that the different coatings are configured to have absorption spectra that each correspond to a portion of an emission spectrum from the same glare-producing light source. In these embodiments, the combined absorption spectra from the coatings may correspond to the desired glare-producing portion of the emission spectrum of the glare-producing light source. In other embodiments, the different coatings may have different chemical and/or physical properties such that the different coatings are configured to have absorption spectra that each correspond to an emission spectrum, or portion thereof, from a different glare-producing light source.

In some cases, the coating is on substantially the whole surface of the optical substrate. For example, the coating may be on substantially the whole of one side of the optical substrate. In some instances, the coating may be on a portion of one surface of the optical substrate. In these embodiments, the optical substrate may have the coating on a portion of the optical substrate, where the portion of the optical substrate with the coating reduces glare from glare-producing light. The portion of the optical substrate that does not have a coating may be substantially transparent. For instance, the coating may be on less than 100% of the surface area of one surface of the optical substrate, such as 95% or less, including 90% or less, or 85% or less, or 80% or less, or 75% or less, or 70% or less, or 65% or less, or 60% or less, or 55% or less, or 50% or less of one surface of the optical substrate. In certain cases, the coating is on 85% or less of the surface of the optical substrate (e.g., the coating covers 85% or less of one surface of the optical substrate).

In certain embodiments, the coating is a uniform coating on the surface of the optical substrate. A uniform coating may be configured to have a substantially constant optical density. As described above, the uniform coating may be on substantially the whole of one side of the optical substrate. In some instances, the coating may be on a portion of one surface of the optical substrate. For instance, the uniform coating may be on less than 100% of the surface area of one surface of the optical substrate, such as 95% or less, including 90% or less, or 85% or less, or 80% or less, or 75% or less, or 70% or less, or 65% or less, or 60% or less, or 55% or less, or 50% or less of one surface of the optical substrate. In certain cases, the uniform coating is on 85% or less of the surface of the optical substrate (e.g., the uniform coating covers 85% or less of one surface of the optical substrate). In certain cases, the uniform coating is on 50% or less of the surface of the optical substrate (e.g., the uniform coating covers 50% or less of one surface of the optical substrate).

In other instances, the coating is a gradient coating on the surface of the optical substrate. A gradient coating may be configured to have a gradient optical density. For example, the coating may have a decreasing gradient-optical density. A decreasing gradient-optical density coating may have a maximum optical density in a first area of the coating and an optical density less than the maximum optical density in a second area of the coating. In some cases, the decreasing gradient- optical density coating decreases in optical density along a certain direction. For instance, the decreasing gradient- optical density coating may have an optical density that decreases in a vertical direction, such that the optical density of the coating gradually decreases from a maximum optical density at or near the top of the optical substrate to a minimum optical density towards the bottom of the optical substrate, or such that the optical density of the coating gradually decreases from a maximum optical density at or near the bottom of the optical substrate to a minimum optical density towards the top of the optical substrate. In other embodiments, the decreasing gradient-optical density coating may have an optical density that decreases in a horizontal direction, such that the optical density of the coating gradually decreases from a maximum optical density at or near one side of the optical substrate (e.g., left side or right side) to a minimum optical density towards the opposite side of the optical substrate (e.g., right side or left side).

For instance, in embodiments where the optical filter is an eyewear lens, the decreasing gradient-optical density coating may have an optical density that decreases in a horizontal direction, such that the optical density of the coating gradually decreases from a maximum optical density at the left side of the optical substrate to a minimum optical density at the right side of the optical substrate (e.g., for left-sided oncoming traffic, such as in the United States). A decreasing gradient-optical density coating oriented as described above may facilitate a reduction in glare and/or photophobia for subjects driving on the right-side of the road and facing oncoming headlights from the left-side of the road. In some instances, a decreasing gradient-optical density coating oriented as described above may facilitate increased light transmission on the right side of the optical substrate, which in turn may facilitate viewing of pedestrians, bike riders, obstacles, etc. on the right side of the road where they may be difficult to discern in conditions of reduced illumination (e.g., dusk, nighttime, early morning, etc.).

Similarly, the decreasing gradient-optical density coating may have an optical density that decreases in a horizontal direction, such that the optical density of the coating gradually decreases from a maximum optical density at or near the right side of the optical substrate to a minimum optical density towards the left side of the optical substrate (e.g., for right-sided oncoming traffic, such as in the United Kingdom, Australia, Japan, India). A decreasing gradient-optical density coating oriented as described above may facilitate a reduction in glare and/or photophobia for subjects driving on the left-side of the road and facing oncoming headlights from the right-side of the road. In some instances, a decreasing gradient-optical density coating oriented as described above may facilitate increased light transmission on the left side of the optical substrate, which in turn may facilitate viewing of pedestrians, bike riders, obstacles, etc. on the left side of the road where they may be difficult to discern in conditions of reduced illumination (e.g., dusk, nighttime, early morning, etc.).

In certain embodiments, a gradient coating is configured to have a gradient-optical density by varying the thickness of the coating. The thickness of the coating may be thickest where the gradient-optical density coating has a maximum in the optical density. The thickness of the coating may be thinnest where the gradient-optical density coating has a minimum in the optical density. The thickness of the coating may gradually decrease from the area where the coating is the thickest to the area where the coating is the thinnest to provide the gradient-optical density coating. For example, the coating may have a maximum thickness in a first area of the coating and a thickness less than the maximum thickness in a second area of the coating. In some cases, the decreasing gradient- optical density coating decreases in thickness along a certain direction. For instance, the decreasing gradient- optical density coating may have a thickness that decreases in a vertical direction, such that the thickness of the coating gradually decreases from a maximum thickness at or near the top of the optical substrate to a minimum thickness towards the bottom of the optical substrate, or such that the thickness of the coating gradually decreases from a maximum thickness at or near the bottom of the optical substrate to a minimum thickness towards the top of the optical substrate. In other embodiments, the decreasing gradient-optical density coating may have thickness that decreases in a horizontal direction, such that the thickness of the coating gradually decreases from a maximum thickness at or near one side of the optical substrate (e.g., left side or right side) to a minimum thickness towards the opposite side of the optical substrate (e.g., right side or left side).

For instance, in embodiments where the optical filter is an eyewear lens, the decreasing gradient-optical density coating may have a thickness that decreases in a horizontal direction, such that the thickness of the coating gradually decreases from a maximum thickness at the left side of the optical substrate to a minimum thickness at the right side of the optical substrate (e.g., for subjects driving on the right side of the road with left-sided oncoming traffic, such as in the United States). A decreasing gradient-optical density coating configured as described above may facilitate a reduction in glare and/or photophobia for subjects driving on the right-side of the road and facing oncoming headlights from the left-side of the road. In some instances, a decreasing gradient-optical density coating configured as described above may facilitate increased light transmission on the right side of the optical substrate, which in turn may facilitate viewing of pedestrians, bike riders, obstacles, etc. on the right side of the road where they may be difficult to discern in conditions of reduced illumination (e.g., dusk, nighttime, early morning, etc.).

Similarly, the decreasing gradient-optical density coating may have a thickness that decreases in a horizontal direction, such that the thickness of the coating gradually decreases from a maximum thickness at or near the right side of the optical substrate to a minimum thickness towards the left side of the optical substrate (e.g., for subjects driving on the left side of the road with right-sided oncoming traffic, such as in the United Kingdom, Australia, Japan, India). A decreasing gradient-optical density coating configured as described above may facilitate a reduction in glare and/or photophobia for subjects driving on the left-side of the road and facing oncoming headlights from the right-side of the road. In some instances, a decreasing gradient-optical density coating configured as described above may facilitate increased light transmission on the left side of the optical substrate, which in turn may facilitate viewing of pedestrians, bike riders, obstacles, etc. on the left side of the road where they may be difficult to discern in conditions of reduced illumination (e.g., dusk, nighttime, early morning, etc.).

In some embodiments, the decreasing gradient-optical density coating is on substantially the whole surface of the optical substrate, such that the decreasing gradient-optical density coating extends from one edge of the optical substrate to the opposite edge of the optical substrate. In some instances, the decreasing gradient-optical density coating may be on a portion of one surface of the optical substrate. For instance, the decreasing gradient-optical density coating may be on less than 100% of the surface area of one surface of the optical substrate, such as 95% or less, including 90% or less, or 85% or less, or 80% or less, or 75% or less, or 70% or less, or 65% or less, or 60% or less, or 55% or less, or 50% or less of one surface of the optical substrate. In certain cases, the decreasing gradient-optical density coating is on 85% or less of the surface of the optical substrate (e.g., the decreasing gradient-optical density coating covers 85% or less of one surface of the optical substrate). In some instances, the decreasing gradient-optical density coating is on 50% or less of the surface of the optical substrate (e.g., the decreasing gradient-optical density coating covers 50% or less of one surface of the optical substrate).

FIG. 4 shows a drawing of an optical filter (e.g., a left eye spectacle lens) with a decreasing gradient-optical density coating. As shown in FIG. 4, the decreasing gradient-optical density coating has an optical density that decreases in a horizontal direction. The decreasing gradient-optical density coating is on the right half of the lens with a maximum optical density at the center of the lens and a minimum optical density at the right edge of the lens. The embodiment shown in FIG. 4 is an example of an optical substrate, where the decreasing gradient-optical density coating is on 50% or less of the surface of the optical substrate. For instance, as shown in FIG. 4, the coating may be substantially uniform on the left portion of the lens and a decreasing gradient-optical density coating covers the right portion of the lens. As shown in FIG. 4, the left half of the lens has a uniform coating that has the same or greater optical density as the maximum optical density of the decreasing gradient-optical density coating on the right half of the lens. The optical filter shown in FIG. 4 may facilitate a reduction in glare and/or photophobia for subjects driving on the right side of the road with left-sided oncoming traffic. Other embodiments of the optical filters may be configured for driving on the left side of the road with right-sided oncoming traffic as described above.

In certain embodiments, the coating includes a metal (e.g., aluminum, silver, molybdenum, tungsten, etc.), a metal fluoride (e.g., magnesium fluoride, calcium fluoride, etc.), a metal oxide (e.g., SiO_2, Al_2O_3, TiO_2, Ta_2O_5, etc.), silicon, a dye, combinations thereof, and the like. In some instances, the coating includes a metal oxide, such as, but not limited to, SiO_2, Al_2O_3, TiO_2, Ta_2O_5, combinations thereof, and the like. In certain cases, the coating is a multi-layer coating that includes two or more layers. In some instances, a layer has different chemical and/or physical properties as an adjacent layer. For example, the coating may include a first layer having a first set of chemical and/or physical properties, and a second layer having a second set of chemical and/or physical properties different from the first set. In some cases, the layers that have different chemical and/or physical properties are made from different materials, such as different metal oxides, as described above.

In certain embodiments, the coating has an optical density of 0.9 or less, such as 0.85 or less, or 0.8 or less, or 0.75 or less, or 0.7 or less, or 0.65 or less, or 0.6 or less, or 0.55 or less, or 0.5 or less, or 0.45 or less, or 0.4 or less, or 0.35 or less, or 0.3 or less, or 0.25 or less, or 0.2 or less, or 0.15 or less, or 0.1 or less, or 0.05 or less. In some embodiments, the coating has an optical density ranging from 0.1 to 0.9, such as from 0.1 to 0.8, including from 0.1 to 0.7, or from 0.1 to 0.6, or from 0.1 to 0.5, or from 0.15 to 0.5, or from 0.2 to 0.5, or from 0.2 to 0.45, or from 0.2 to 0.4. For example, the coating may have an optical density of 0.2. In some embodiments, the coating has an optical density of 0.25. In some cases, the coating has an optical density of 0.3. In other instances, the coating has an optical density of 0.35. In some embodiments, the coating has an optical density of 0.4. In certain cases, the coating has an optical density of 0.45.

DEVICES

Aspects of the present disclosure include devices that include an optical filter as described herein. In certain embodiments, the device may include an article of eyewear. The article of eyewear may include a lens and a coating on at least a portion of a surface of the lens. For example, the article of eyewear may include, but is not limited to spectacles (e.g., glasses), contact lenses, intraocular lenses, clip-on glasses, fitovers, goggles, and the like. The article of eyewear may include a corrective lens (i.e., a prescription lens) or a non-corrective lens (i.e., a non-prescription lens) that has the coating on at least a portion of a surface of the lens. In certain instances, the lens without the optical filter includes a substantially transparent material. For example, the lens may include a glass, such as crown glass, fused silica, and the like. In some cases, the lens is a plastic, such as, but not limited to, allyl diglycol carbonate (i.e., CR-39), polycarbonate, Trivex®, high-index plastic, ultra-high index plastic, and the like. The coating for the lens of the article of eyewear may have the physical and/or chemical properties as described above.

In certain embodiments, the article of eyewear includes two lenses, such as a left lens and a right lens. In these embodiments, one or both of the lenses may be configured as an optical filter as described herein. In some cases, the article of eyewear may include a first lens configured as an optical filter and a second non-filtered lens. For example, the article of eyewear may include an optical filter as the left lens and a non-filtered lens as the right lens. Embodiments where only the left lens includes an optical filter may facilitate a reduction in glare and/or photophobia for a subject driving in left-sided oncoming traffic (e.g., in the United States). In other embodiments, the article of eyewear may include an optical filter as the right lens and a non-filtered lens as the left lens. Embodiments where only the right lens includes an optical filter may facilitate a reduction in glare and/or photophobia for a subject driving in right-sided oncoming traffic (e.g., in the United Kingdom, Australia, Japan, India).

In certain embodiments, the article of eyewear includes two lenses. In these cases, both the left and right lenses in the article if eyewear may include optical filters. Embodiments where both the left and right lenses include optical filters may facilitate a reduction in glare and/or photophobia for a subject driving in either left-sided oncoming traffic or right-sided oncoming traffic.

In other embodiments, the article of eyewear includes gradient-optical density filters on one or both of the left and right lenses of the article of eyewear. The lenses may have decreasing gradient-optical density coatings with optical densities that decrease in a horizontal direction, as described above. The horizontally decreasing gradient-optical density coatings may be oriented for either left-sided oncoming traffic or right-sided oncoming traffic, as described above.

In certain embodiments, the coating is on substantially the whole surface of the optical substrate (e.g., the lens). In some instances, the coating may be on a portion of one surface of the lens. For instance, the coating may be on less than 100% of the surface area of one surface of the lens, such as 95% or less, including 90% or less, or 85% or less, or 80% or less, or 75% or less, or 70% or less, or 65% or less, or 60% or less, or 55% or less, or 50% or less of one surface of the lens. In certain cases, the coating is on 85% or less of the surface of the lens (e.g., the coating covers 85% or less of one surface of the lens). In some instances, the coating is on 50% or less of the surface of the lens (e.g., the coating covers 50% or less of one surface of the lens).

In some cases, the coating is on substantially the whole surface of both sides of the optical substrate. For example, the coating may be on substantially the whole of a first side (e.g., a front side) of the optical substrate and on substantially the whole of a second side (e.g., a back side) of the optical substrate. In some instances, the coating may be on a portion of the surfaces (e.g., front and back surfaces) of the optical substrate. In these embodiments, the optical substrate may have the coating on a portion of the surfaces of the optical substrate, where the portion of the surfaces of the optical substrate with the coating reduces glare from glare-producing light. The portion of the surfaces of the optical substrate that does not have a coating may be substantially transparent. For instance, the coating may be on less than 100% of the combined surface areas of the surfaces (e.g., front and back surfaces) of the optical substrate, such as 95% or less, including 90% or less, or 85% or less, or 80% or less, or 75% or less, or 70% or less, or 65% or less, or 60% or less, or 55% or less, or 50% or less of the surfaces of the optical substrate. In certain cases, the coating is on 85% or less of the surfaces of the optical substrate (e.g., the coating covers 85% or less of the front and back surfaces of the optical substrate). In embodiments where there is a coating on both the front and back surfaces of the optical substrate, the coatings may be uniform coatings or gradient coatings or combinations thereof, as described above. For example, both the front and back surfaces of the optical substrate may have uniform coatings, both the front and back surfaces of the optical substrate may have gradient coatings, the front surface may have a uniform coating and the back surface may have a gradient coating, or the front surface may have a gradient coating and the back surface may have a uniform coating.

In certain embodiments, the optical filters described herein optionally have one or more additional coatings. For example, the optical filter may include one or more additional coatings, such as, but not limited to, an anti-reflective coating, a scratch resistant coating, an anti-fog coating, a coating configured to repel water, a coating configured to repel grease, and the like, and combinations thereof. In some cases, the optical filters include an additional coating configured to absorb ultraviolet (UV) light (e.g., a UV coating). For instance, the UV coating may be configured to absorb light in the UV range of the electromagnetic spectrum, such as 400 nm or less. In some embodiments, the UV coating is configured to absorb light with a wavelength ranging from 200 nm to 400 nm, such as from 210 nm to 400 nm, including from

220 nm to 400 nm, or from 230 nm to 400 nm, or from 240 nm to 400 nm, or from 250 nm to 400 nm, or from 260 nm to 400 nm, or from 270 nm to 400 nm, or from 280 nm to 400 nm, or from 290 nm to 400 nm, or from 300 nm to 400 nm, or from 310 nm to 400 nm, or from 320 nm to 400 nm, or from 330 nm to 400 nm, or from 340 nm to 400 nm, or from 350 nm to 400 nm. In certain embodiments, the UV coating is configured to absorb light with a wavelength ranging from 320 nm to 400 nm. In certain instances, the UV coating is configured to have an average light transmittance of 0% to 50% at a wavelength ranging from 320 nm to 400 nm, such as an average light transmittance of 0% to 45%, or 0% to 40%, or 0% to 35%, or 0% to 30%, or 0% to 25%, or 0% to 20%, or 0% to 15%, or 0% to 10% at a wavelength ranging from 320 nm to 400 nm.

Aspects of the present disclosure also include devices configured to test the subject optical filters. In some cases, the testing device is configured to test the effectiveness of the optical filters disclosed herein for reducing glare from glare-producing light. For example, the testing device may be configured to test the effectiveness of the optical filters disclosed herein for reducing glare from glare-producing light in ambient light or conditions of reduced illumination (e.g., under scotopic conditions). In some cases, the testing device is configured to test the effect of the optical filters disclosed herein on a subject's visual function, such as the effect on one or more of a subject's visual acuity, contrast sensitivity, foveal sensitivity and parafoveal sensitivity.

In certain embodiments, the testing device includes a light source. The light source may be any type of glare-producing light source as described herein, including, but not limited to, HID, LED, metal-halide lights, and the like. In addition, the testing device may be configured to position a subject in the path of illumination (e.g., in the beam of light) emitted from the light source. For instance, the testing device may be configured to position a subject's eye (or eyes) in the beam of light from the light source. In certain embodiments, the testing device includes an optical filter, such as an optical filter as described herein. The testing device may be configured such that the optical filter is positioned between the light source and the subject. For instance, the optical filter may be positioned between the light source and the subject such that light from the light source passes through the optical filter before reaching the subject. In certain instances, the testing device is configured such that the optical filter is removable and replaceable. Embodiments where the optical filter is removable may facilitate testing of different types of optical filters or for obtaining control measurements, such as in the absence of an optical filter or with a plano (blank) lens.

METHODS

Aspects of the present disclosure include a method of reducing glare from a glare-producing light source. The method includes positioning an optical filter between the glare-producing light source and a subject. The optical filter is an optical filter as described herein. For instance, the optical filter may be configured to have an absorption spectrum that is correlated to the emission spectrum of the glare-producing light source. For example, the optical filter may be configured to have an absorption spectrum that is correlated to the emission spectrum of the glare-producing light source at wavelengths of 500 nm or less. The optical filter may be positioned in proximity to the subject's eyes, such as incorporated into spectacles (e.g., glasses), contact lenses, intraocular lenses, clip-on glasses, fitovers, goggles, and the like. In other instances, the optical filter may be positioned at a distance from the subject's eyes, such as incorporated into a window positioned between the glare-producing light source and the subject. For example, the optical filter may be incorporated into an automotive windshield between the glare-producing light source and the subject. In some cases, the optical filter may be incorporated into an automotive mirror, such as a rear view mirror or side view mirrors.

In certain embodiments, the method includes selecting an optical filter such that the optical filter is configured to have an absorption spectrum that is correlated to the emission spectrum of the glare-producing light source, as described in detail herein. For example, the optical filter may be selected to have an absorption spectrum that is correlated to the emission spectrum of the glare-producing light source at wavelengths of 500 nm or less.

As described above, the glare-producing light source may be one or more of a high-intensity discharge (HID) headlight and a light-emitting diode (LED) headlight. As such, the optical filter may be positioned such that glare is reduced in a subject exposed to one or more of the HID headlight and the LED headlight. For example, as described above, the optical filter may be incorporated into an article of eyewear worn by a subject exposed to one or more of the HID headlight and the LED headlight, such as when the subject is driving. In some cases, as described above, the optical filter may be incorporated into an automotive windshield between one or more of the HID and LED headlight and the subject, such as on a surface of the windshield in an automobile driven by the subject. In certain instances, the optical filter may be incorporated into an automotive mirror (e.g., rear view mirror or side view mirrors) that reflects light from one or more of the HID and LED headlight to the subject.

In certain embodiments, the glare-producing light source may a metal-halide light source, such as a stadium light. As such, the optical filter may be positioned such that glare is reduced in a subject exposed to a metal-halide light source, such as a stadium light. For example, as described above, the optical filter may be incorporated into an article of eyewear worn by a subject exposed to a metal-halide light source, such as a stadium light, such as, but not limited to, spectacles (e.g., glasses), contact lenses, intraocular lenses, clip-on glasses, fitovers, goggles, and the like. In some instances, a subject may be exposed to a metal-halide light source, such as a stadium light when the subject is engaging in an activity in a stadium or an arena, such as, but not limited to, an athletic or sporting activity (e.g., baseball, football, basketball, tennis, softball, etc.). In some instances, a subject may be exposed to a metal-halide light source, such as a stadium light or photographic or production lighting when the subject is a musician, and the like.

Aspects of the present disclosure also include a method of reducing discomfort glare from a discomfort glare-inducing light source. The method includes positioning an optical filter between the discomfort glare-inducing light source and a subject. The optical filter may be positioned in proximity to the subject's eyes, such as incorporated into spectacles (e.g., glasses), contact lenses, intraocular lenses, clip-on glasses, fitovers, goggles, and the like. In other instances, the optical filter may be positioned at a distance from the subject's eyes, such as incorporated into a window positioned between the discomfort glare-inducing light source and the subject. For example, the optical filter may be incorporated into an automotive windshield between the discomfort glare-inducing light source and the subject. In some instances, the optical filter may be incorporated into an automotive mirror (e.g., rear view mirror or side view mirrors) that reflects light from one or more of the HID and LED headlight to the subject.

In certain embodiments, the method includes reducing glare and/or photophobia in a subject without a significant decrease in the subject's contrast sensitivity. For example, the optical filter may be configured such that the subject's contrast sensitivity is reduced by 25% or less when using the optical filter as compared to when not using the optical filter (or when using a blank filter), such as a reduction in contrast sensitivity of 20% or less, including 15% or less, or 10% or less, or 5% or less, or 4% or less, or 3% or less, or 2% or less, or 1% or less. In some cases, the method includes reducing glare and/or photophobia in a subject without a significant decrease in the subject's contrast sensitivity in ambient (e.g., daylight) or reduced illumination (e.g., scotopic) conditions.

In certain embodiments, the method includes reducing glare and/or photophobia in a subject without a significant decrease in the subject's foveal sensitivity. For example, the optical filter may be configured such that the subject's foveal sensitivity is reduced by 25% or less when using the optical filter as compared to when not using the optical filter (or when using a blank filter), such as a reduction in foveal sensitivity of 20% or less, including 15% or less, or 10% or less, or 5% or less, or 4% or less, or 3% or less, or 2% or less, or 1% or less. In some cases, the method includes reducing glare and/or photophobia in a subject without a significant decrease in the subject's contrast sensitivity and/or foveal sensitivity as described above in ambient (e.g., daylight) or reduced illumination (e.g., scotopic) conditions.

In certain embodiments, the method includes reducing glare and/or photophobia in a subject without a significant decrease in the subject's parafoveal sensitivity. For example, the optical filter may be configured such that the subject's parafoveal sensitivity is reduced by 25% or less when using the optical filter as compared to when not using the optical filter (or when using a blank filter), such as a reduction in parafoveal sensitivity of 20% or less, including 15% or less, or 10% or less, or 5% or less, or 4% or less, or 3% or less, or 2% or less, or 1% or less. In some cases, the method includes reducing glare and/or photophobia in a subject without a significant decrease in the subject's contrast sensitivity and/or foveal sensitivity and/or parafoveal sensitivity as described above in ambient (e.g., daylight) or reduced illumination (e.g., scotopic) conditions.

In certain embodiments, the method includes reducing glare and/or photophobia in a subject without a significant decrease in the subject's visual acuity. For example, the optical filter may be configured such that the subject's visual acuity is reduced by 25% or less when using the optical filter as compared to when not using the optical filter (or when using a blank filter), such as a reduction in visual acuity of 20% or less, including 15% or less, or 10% or less, or 5% or less, or 4% or less, or 3% or less, or 2% or less, or 1% or less. In some cases, the method includes reducing glare and/or photophobia in a subject without a significant decrease in the subject's contrast sensitivity and/or foveal sensitivity and/or parafoveal sensitivity and/or visual acuity as described above in ambient (e.g., daylight) or reduced illumination (e.g., scotopic) conditions.

In certain embodiments, the subject is a subject diagnosed with an eye disease, such as a subject diagnosed with a macular disease. In some cases, the subject has been diagnosed with age-related macular degeneration. In these embodiments, the method may facilitate a reduction in glare from a light source and/or a reduction in photophobia from the light source in the subject diagnosed with a macular disease (e.g., age-related macular degeneration). In certain instances, the method may facilitate a reduction in photostress caused by the light source in the subject. For instance, the method may facilitate a reduction in photostress in subjects diagnosed with an eye disease, such as a macular disease (e.g., age-related macular degeneration).

Aspects of the present disclosure also include a method for testing an optical filter. In some cases, the testing uses a testing device as described above. The testing method may be configured to test the effectiveness of the optical filters disclosed herein for reducing glare from glare-producing light. For example, the testing method may be configured to test the effectiveness of the optical filters disclosed herein for reducing glare from glare-producing light in ambient light or conditions of reduced illumination (e.g., under scotopic conditions). In some cases, the testing method is configured to test the effect of the optical filters disclosed herein on a subject’s visual function, such as the effect on one or more of a subject’s visual acuity, contrast sensitivity, foveal sensitivity and parafoveal sensitivity.

In certain embodiments, the testing method includes positioning a subject in the testing device. For instance, the testing method may include positioning the subject in the path of illumination (e.g., in the beam of light) emitted from the light source of the testing device. The light source may be any type of glare-producing light source as described herein, including, but not limited to, HID, LED, metal-halide lights, and the like. In some cases, the testing method includes positioning a subject’s eye (or eyes) in the beam of light from the light source of the testing device. The method may include obtaining control measurements of a subject’s visual function, such as visual acuity, contrast sensitivity, foveal sensitivity and parafoveal sensitivity. For example, the control measurements may be obtained in the absence of an optical filter or with a plano (blank) lens. In certain embodiments, the testing method includes placing an optical filter between the light source and the subject. For instance, the testing method may include placing the optical filter between the light source and the subject such that light from the light source passes through the optical filter before reaching the subject. The method may further include obtaining measurements of the subject’s visual function when an optical filter is positioned between the light source and the subject. In certain instances, the testing method also includes removing the optical filter and replacing the optical filter with a different optical filter. Additional measurements of the subject’s visual function may be obtained with different optical filters.

Embodiments of the present disclosure also include a method of producing an optical filter as described herein. The method includes contacting at least a portion of a surface of an optical substrate with a coating. As described herein, the coating may be configured to have a multimodal (e.g., bimodal) absorption spectrum for glare-producing light to produce an optical filter. The step of coating the surface of the optical substrate may be performed using any convenient coating protocol as desired, such as, but not limited to, dip coating, spin coating, spray coating, thin layer deposition techniques (e.g., physical vapor deposition (PVD) or chemical layer deposition (CVD)), combinations thereof, and the like.

In certain embodiments, the method includes coating at least a portion of a surface of an optical substrate using physical vapor deposition, such as, but not limited to, ion beam sputtering, electron beam evaporation, ion assisted evaporation, and the like. In certain instances, the method includes coating at least a portion of the surface of the optical substrate using ion-assisted evaporation (also known as electron beam evaporation with ion assist or ion-assisted deposition). In some cases, ion-assisted evaporation includes directing an evaporated metal and an ion source towards the surface of the optical substrate. The evaporated metal may be produced by heating a metal source or by electron beam bombardment in a vacuum chamber, which produces a stream of evaporated metal that can be directed towards the surface of the optical substrate. In some instances, the ion source includes high energy ions, such as oxygen ions. In certain cases, the evaporated metal and the ion source are directed towards the surface of the substrate substantially simultaneously. In some cases, the method of coating includes cooling the optical substrate during the coating process. For instance, the optical substrate may be cooled, such that the temperature is 125 °C or less, or 100 °C or less, or 95 °C or less, or 90 °C or less, or 85 °C or less, or 80 °C or less, or 75 °C or less.

UTILITY

The optical filters and devices find use in a variety of different applications where reducing discomfort glare and/or photophobia from a light source is desired. For example, the optical filters and devices find use in reducing discomfort glare and/or photophobia in a subject exposed to a light source, such as a discomfort glare-producing light source and/or a photophobia-inducing light source. As such, in certain embodiments, the optical filters and devices find use in reducing discomfort glare and/or photophobia in a subject exposed to a HID or LED light source, such as HID or LED headlights. Accordingly, the optical filters and devices find use in facilitating a reduction in discomfort glare and/or photophobia in drivers at nighttime who face oncoming traffic with HID and/or LED headlights.

In certain embodiments, the optical filters and devices disclosed herein find use in reducing discomfort glare and/or photophobia in a subject exposed to a metal-halide light source, such as a stadium light. Accordingly, the optical filters and devices find use in facilitating a reduction in discomfort glare and/or photophobia in subjects exposed to a metal-halide light source, for example subjects engaged in an activity in a stadium or an arena, such as an athletic or sporting activity (e.g., baseball, football, basketball, tennis, softball, etc.), or other subjects who may be exposed to a metal-halide light source, such as, but not limited to, subjects exposed to photographic or production lighting (e.g., a musician), and the like.

For example, in some instances, metal-halide lights (e.g., stadium lights) can emit significant levels of blue light (see FIG. 14). These lights are commonly used for night time sporting activities, such as, but not limited to, baseball, football, basketball, tennis, softball, etc. In some cases, the blue light emitted by metal-halide lights causes symptomatic glare in susceptible individuals. As a result, a subject experiencing such symptomatic glare who is participating in the sporting activity may have difficulty seeing objects. For example, a baseball or tennis ball can be “lost in the lights”. For instance, a baseball player attempting to catch a high, fly ball or pop-up can suffer significant glare while looking upwards into the stadium lights. In some instances, the glare may cause the player to misjudge or lose track of the trajectory of the ball, such that ball is dropped or missed. Similarly, a tennis player may look up while serving the ball or trying to smash a lob and lose the ball in the glare of bright stadium lights.

As such, the optical filters disclosed herein find use in reducing discomfort glare and/or photophobia in a subject exposed to a metal-halide light source, such as a stadium light. For example, to reduce stadium light glare, an optical filter that has an absorption spectrum corresponding to the blue light components (e.g., from 400-500 nm) of the emitted light from the stadium lights may be used. In certain embodiments, the glare-producing light from the stadium lights is blocked with an optical filter having an optical density sufficient to minimize glare symptoms while not causing a decrease in visual function (e.g., without a significant decrease in a subject’s visual acuity, contrast sensitivity, foveal sensitivity or parafoveal sensitivity). In certain instances, the optical density of the optical filter ranges from 0.1 to 0.9, such as from 0.1 to 0.8, including from 0.1 to 0.7, or from 0.1 to 0.6, or from 0.1 to 0.5, or from 0.15 to 0.5, or from 0.2 to 0.5, or from 0.2 to 0.45, or from 0.2 to 0.4. In certain embodiments, the optical filter has an optical density ranging from 0.2 to 0.4. In some instances, the optical filter includes a coating on a lens for spectacles (e.g., glasses), contact lenses, intraocular lenses, clip-on glasses, fitovers, goggles, and the like, or may include a coating on the stadium lights themselves. In some instances, the optical density of the optical filter may be customized to the needs of the individual player. Additional portions or all of near visible UV light (e.g., 300-400 nm) may also be absorbed by the optical filter. Additional coatings may also be included on the optical filter, such as, but not limited to, on or more of an anti-reflective coating, a scratch resistant coating, a UV coating, an anti-fog coating, a coating configured to repel water, a coating configured to repel grease, and the like, as described herein.

The subject optical filters and devices also find use for subjects exposed to artificial lighting conditions illuminated by LED, HID or metal-halide lighting, such as photographic lighting or production lighting on a television or movie set, and the like. As described herein, such optical filters find use in minimizing glare symptoms by reduce blue and/or ultraviolet light components of the glare-producing light. In certain instances, the optical filters reduce glare from glare-producing light at an optical density which preserves visual function (e.g., without a significant decrease in a subject’s visual acuity, contrast sensitivity, foveal sensitivity or parafoveal sensitivity). As described herein, the optical filter may include a coating on a lens for spectacles (e.g., glasses), contact lenses, intraocular lenses, clip-on glasses, fitovers, goggles, and the like, or may include a coating on the lights themselves. Such optical filters may also be worn in ambient lighting conditions (e.g., sunlight) to reduce glare symptoms as described herein.

The subject optical filters and devices also find use for subjects exposed to glare-producing light from a display device, such as, but not limited, to display devices in a television, a desktop computer, a laptop computer, a tablet computer, a cellphone, an mp3 player, and the like. As described herein, such optical filters find use in minimizing glare symptoms by reduce blue and/or ultraviolet light components of the glare-producing light. In certain instances, the optical filters reduce glare from glare-producing light at an optical density which preserves visual function (e.g., without a significant decrease in a subject's visual acuity, contrast sensitivity, foveal sensitivity or parafoveal sensitivity). As described herein, the optical filter may include a coating on a lens for spectacles (e.g., glasses), contact lenses, intraocular lenses, clip-on glasses, fitovers, goggles, and the like, or may include a coating on the display device itself. Such optical filters may also be worn in ambient lighting conditions (e.g., sunlight) to reduce glare symptoms as described herein.

In some instances, as older drivers develop media opacities such as cataract and/or macular dysfunction (e.g., macular degeneration), both disability and discomfort glare can be aggravated. As such, the optical filters and devices find use in facilitating a reduction in glare and/or photophobia in subjects diagnosed with an eye disease, such as a macular disease (e.g., age-related macular degeneration). In some cases, the optical filters find use in reducing photostress in subjects diagnosed with an eye disease, such as a macular disease (e.g., age-related macular degeneration).

The optical filters and devices also find use in reducing glare and/or photophobia from a light source without a substantial decrease in visual function in the subject. For example, the optical filters and devices also find use in reducing glare and/or photophobia from a light source without a substantial decrease in visual acuity, contrast sensitivity, foveal sensitivity or parafoveal sensitivity in the subject.

KITS

Also provided are kits that find use in practicing the methods, as described above. For example, a kit for practicing the methods may include an optical filter, such as a lens with a coating as described herein. The kit may also include one or more optical filter accessories, such as, but not limited to, a cleaning solution, a cleaning cloth, a case for the optical filter, and the like. For example, in embodiments where the optical filter is provided as part of an article of eyewear, the kit may include one or more eyewear accessories, such as an eyewear cleaning solution, an eyewear cleaning cloth, an eyewear case, etc.

In addition to the above components, the kits may further include instructions for practicing the methods. These instructions may be present in the kits in a variety of forms, one or more of which may be present in the kit. One form in which these instructions may be present is as printed information on a suitable medium or substrate, e.g., a piece or pieces of paper on which the information is printed, in the packaging of the kit, in a package insert, etc. Another means would be a computer readable medium, e.g., CD, DVD, Blu-ray, computer-readable memory, etc., on which the information has been recorded or stored. Yet another means that may be present is a website address which may be used via the Internet to access the information at a removed site. Any convenient means may be present in the kits.

As can be appreciated from the disclosure provided above, the present disclosure has a wide variety of applications. Accordingly, the following examples are offered for illustration purposes and are not intended to be construed as a limitation on the invention in any way. Those of skill in the art will readily recognize a variety of noncritical parameters that could be changed or modified to yield essentially similar results. Thus, the following examples are put forth so as to provide those of ordinary skill in the art with a complete disclosure and description of how to make and use the present invention, and are not intended to limit the scope of what the inventors regard as their invention nor are they intended to represent that the experiments below are all or the only experiments performed. Efforts have been made to ensure accuracy with respect to numbers used (e.g. amounts, temperature, etc.) but some experimental errors and deviations should be accounted for. Unless indicated otherwise, parts are parts by weight, molecular weight is weight average molecular weight, temperature is in degrees Celsius, and pressure is at or near atmospheric.

EXAMPLES

EXAMPLE 1

Embodiments of the optical filters described herein were tested for reducing glare and photophobia in subjects. The optical filters effects on contrast sensitivity, foveal sensitivity and parafoveal sensitivity were also tested.

Methods

The sequence of testing was as follows: (1) contrast sensitivity testing; (2) foveal sensitivity testing; (3) parafoveal sensitivity testing; (4) exposure to Keeler Indirect Ophthalmoscope with LED light source and testing of foveal sensitivity; and (5) subjective glare discomfort/photosensitivity assessment after exposure to Keeler Indirect Ophthalmoscope with LED light source.

Two filters were used during the testing procedures – a blank (plano) filter and a bimodal optical filter with a bimodal absorption spectrum as shown in FIG. 2 (0.25 optical density units). The non-tested eye in each subject was patched and remained patched throughout all testing steps.

Contrast sensitivity

Contrast sensitivity tests were performed at room lighting. The subject was seated and a Pelli-Robson contrast sensitivity chart was placed at the subject's eye level 1 meter away. The subject was given a +0.75 lens (to compensate for the 1 meter distance) in addition to the subject's own glasses for distance. One of the filters was held together with the +0.75 lens by the subject and placed as close as possible to the glasses. The subject read the letters in each row of the chart until they were unable to do so. Contrast sensitivity was recorded on a separate Pelli-Robson Contrast Sensitivity sheet. The same procedure was then performed with the other filter. The sequence of filters tested was alternated for randomization. The type of filter used during each test was not known by the subjects. At the end of the test, the subject was asked which filter they preferred in terms of the ability to identify the letters.

Foveal sensitivity

The room lights were turned off and the subject was given 5-7 minutes to dark adapt. The subject's identifying information was put into the Humphrey Visual Field (HVF) machine and 30-2 SITA FAST test was chosen. One of the two filters was placed in the holder, the test was explained to the subject, and after the test was performed, the HVF machine calculated foveal sensitivity (performed in triplicate). The same procedure was then performed with the other filter. The sequence of filters tested was alternated for randomization. The type of filter used during each test was not known by the subjects. If there was a large discrepancy in the calculated sensitivity, the test was performed an additional 1-2 times to obtain reproducible, consistent baseline measurements. At the end of the test, the subject was asked which filter they preferred in terms of the ability to identify the central flashing light stimulus that was used by the HFV machine to calculate foveal sensitivity.

Parafoveal sensitivity

The test on the HFV machine was switched to MACULA FASTPAC or 10-2 SITA FAST. One of the two filters was placed in the holder, the test was explained to the subject, and after the test was performed, the HVF machine calculated sensitivities at each of the appropriate points. The test was performed once for each filter. The sequence of filters tested was alternated for randomization. The identity of each filter was not known by the subjects. At the end of the test the subject was asked which filter they preferred in terms of the ability to identify the paracentral flashing light stimuli that were used by the HFV machine to calculate parafoveal sensitivity.

Effect of Keeler Indirect Ophthalmoscope with LED Light Source Exposure on Foveal Sensitivity

The subject was given 3-5 minutes to dark adapt after foveal and parafoveal sensitivity testing. Foveal sensitivities for each filter were checked once to ensure that the subject was at their baseline measurement (as described above). The HVF machine was switched back to 30-2 SITA FAST test. A Keeler Vantage Plus LED Wireless Indirect Ophthalmoscope was turned to full power and a small diameter white spot was chosen. One of the filters was held next to the subject's glasses and the light was shined through the filter directly into the subject's eye for 5 seconds from 1 foot away. The patient was asked to fixate on the light source during the exposure. The same filter that covered the patient's eye during the light exposure was then immediately put into the holder in the HVF machine. After the test was complete, the machine calculated the foveal sensitivity at time 0, 1 and 2 minutes post-exposure, and every 2 minutes thereafter until the foveal sensitivity returned to the baseline measurement for the specific filter tested. The same procedure was then performed with the other filter. The sequence of filters tested was alternated for randomization. The identity of each filter was not known by the subjects. At the end of the test, the subject was asked which filter they preferred in terms of the ability to identify the central flashing light stimulus that was used by the HFV machine to calculate foveal sensitivity.

Effect of Keeler Indirect Ophthalmoscope with LED Light Source Exposure on glare discomfort and photophobia

A Keeler Vantage Plus LED Wireless Indirect Ophthalmoscope was turned to full power and a small diameter white spot was chosen. One of the filters was held next to the subject's glasses and the light was shined through the filter directly into the subject's eye for 3 seconds from 1 foot away. The subject was asked to fixate on the light source during the exposure. The subject was instructed to assume that the amount of glare discomfort felt after the 3-second exposure with the first filter equaled 100%. The identity of each filter was not known by the subjects. The same procedure was then performed with the other filter and the amount of glare discomfort was subjectively compared to that of the first filter. For example, if the second filter was “more comfortable” then the subject would estimate the amount by which it was “more comfortable”. Subjective comments were also elicited from the subjects in terms of “why they thought one filter or another was more or less comfortable”. When the bimodal optical filter as described herein was shown first (e.g., corresponding to an initial glare discomfort of 100% according to the test protocol), the glare discomfort level for the blank filter (shown second) was always ≥100%. In order to keep data consistent, all glare discomfort data was normalized to the blank filter = 100%. For example, if the bimodal optical filter equaled 100% and blank filter equaled 120%, the relative ratio of blank filter to bimodal optical filter was 1.2, and thus the optical filter would be normalized to 83.3% (e.g., 100/1.2 = 83.3). The amount of glare discomfort for the filters relative to one another was recorded. The sequence of filters tested was alternated for randomization. For assessment of photophobia, while the light was being shined into the subject’s eye, they were asked if the light was “painful” or if they felt a desire to close or avert their eyes. A “yes” response to either one of these questions was recorded as photophobia. A similar procedure for assessment of subjective glare discomfort and photophobia was performed to compare the bimodal optical filter to the plano spectacles with Super High Vision anti-reflective coating (Hoya Filters; THK Photo Products Inc., Huntington Beach, CA). The sequence of testing was alternated for randomization.

Statistics

All statistical analysis was performed using VassarStats: Website for Statistical Computation. Statistical significance was accepted at $p < 0.05$ level.

Results

A total of 32 participants (32 eyes) with subjective symptoms of glare and/or photophobia to headlights during night driving were tested. 12 (38%) right eyes and 20 (62%) left eyes were tested. Males represented 89% and Caucasians 100%. Mean ± SD age was 70.5 ± 9.6 years (range, 52-89 years). Twenty-one (66%) subjects were classified as non-age-related macular degeneration (AMD) with glare and 11 (34%) subjects as AMD with glare. Mean visual acuity for the non-AMD with glare group was 20/25, and mean visual acuity for the AMD with glare group was 20/27. Mean score on the modified NEI-RLQ-42 questionnaire (maximum

= 13 points) was 8.8 points for non-AMD with glare group and 8.5 points for AMD with glare group. All testing results were combined for non-AMD with glare and AMD with glare groups due to similarity of group characteristics to facilitate studying the effects of filters on a broad population of patients with symptomatic glare discomfort and photophobia from headlight exposure.

Contrast, foveal, and parafoveal sensitivities

As shown in FIG. 9, mean ± SD log contrast sensitivity (n=14) was 1.6 ± 0.2 for the blank and bimodal optical filter (p=1.0, Mann-Whitney test), indicating that the bimodal optical filter does not significantly decrease contrast sensitivity as compared to the blank. As shown in FIG. 10, mean ± SD foveal sensitivity (n=26) was 30.3 ± 2.9 for the blank filter and 30.4 ± 2.7 for the bimodal optical filter (p=0.76, Mann-Whitney test), indicating that the bimodal optical filter does not significantly decrease foveal sensitivity as compared to the blank. As shown in FIG. 11, mean ± SD parafoveal sensitivity (n=8) was 26.3 ± 2.0 for the blank filter and 26.4 ± 1.9 for the bimodal optical filter (p=0.96, Mann-Whitney test), indicating that the bimodal optical filter does not significantly decrease parafoveal sensitivity as compared to the blank.

Physiologic photostress response

Ten of 30 (33%) subjects experienced positive physiologic photostress response (i.e., ≥2 minutes to recover pre-exposure foveal sensitivity) after a 5 second exposure to the Keeler Vantage Plus LED Wireless Indirect Ophthalmoscope from 1 foot away at full power. As shown in FIG. 7, mean ± SD (%) reduction in foveal sensitivity after a 5 second exposure was 30.9 ± 7.0% with the blank filter and 21.8 ± 6.6% with the bimodal optical filter (p=0.02, Mann-Whitney test), indicating that, for subjects with photostress, the loss of foveal sensitivity after light exposure was significantly reduced by the bimodal optical filter as compared to the blank. Loss of foveal sensitivity was reduced by the bimodal optical filter vs. blank filter in 10/10 (100%) of the subjects.

Mean ± SD time (minutes) to recovery of pre-exposure foveal sensitivity was 3.6 ± 1.6 minutes with the blank filter and 2.5 ± 1.1 minutes with the bimodal optical filter (p=0.14, Mann-Whitney test). The time required to recovery of pre-exposure foveal sensitivity was decreased by the bimodal optical filter vs. blank filter in 6/10 (60%) subjects. In addition, when the subjects (n=29) were asked which filter they preferred during exposure to the Keeler Vantage Plus LED Wireless Indirect Ophthalmoscope in terms of their ability to identify the central flashing light stimulus utilized by the HVF machine to calculate foveal sensitivity, 15/29

(52%) subjects saw “no difference”, 14/29 (48%) subjects chose the bimodal optical filter ($p<0.0001$, Chi-Square test), and 0/29 (0%) subjects chose the blank.

Glare discomfort and photophobia

Compared to the blank filter, 26/32 (81%) subjects with the bimodal optical filter reported more “comfort” after a 3 second exposure to the Keeler Vantage Plus LED Wireless Indirect Ophthalmoscope from 1 foot away at full power (see FIG. 5). Mean ± SD (%) comfort improvement vs. blank filter was 18.8 ± 7.2% with the HMLOD filter ($p<0.0001$, Mann-Whitney test). These results indicate that glare discomfort was significantly reduced by the bimodal optical filter during light exposure as compared to the blank.

As shown in FIG. 6, of the 18 subjects tested, 11 (61%) subjects with the blank filter and 1 (5.6%) subject with the bimodal optical filter expressed the desire to close their eyes/avert their gaze during a 3 second exposure to the Keeler Vantage Plus LED Wireless Indirect Ophthalmoscope from 1 foot away at full power ($p<0.0001$, Chi-Square test), indicating that photophobia was significantly reduced by the bimodal optical filter during light exposure as compared to the blank.

Compared to plano spectacles with a Super High Vision anti-reflective coating (Hoya Filters; THK Photo Products Inc., Huntington Beach, CA), 10/10 (100%) subjects with the bimodal optical filter reported more “comfort” after a 3 second exposure to the Keeler Vantage Plus LED Wireless Indirect Ophthalmoscope from 1 foot away at full power. As shown in FIG. 8, mean ± SD (%) comfort improvement with bimodal optical filter vs. anti-reflective coating spectacles was 18.0 ± 9.6% (range, 5-32.5%) ($p=0.0002$, Mann-Whitney test), indicating that, as compared to an anti-reflective coating, glare discomfort was significantly reduced by the bimodal optical filter during light exposure.

EXAMPLE 2

Embodiments of the optical filters described herein were tested for reducing glare and photophobia in subjects. The optical filters effects on visual acuity, contrast sensitivity, foveal sensitivity and parafoveal sensitivity were also tested. FIG. 15 shows a graph of percent transmittance vs. wavelength (nm) for embodiments of the subject optical filters used in Example 2 described herein.

Methods

The sequence of testing was as follows: (1) visual acuity testing; (2) contrast sensitivity testing; (3) foveal sensitivity testing; (4) parafoveal sensitivity testing; (5) exposure to Keeler

Indirect Ophthalmoscope with LED light source and testing of foveal sensitivity; and (6) subjective glare discomfort/photosensitivity assessment after exposure to Keeler Indirect Ophthalmoscope with LED light source.

Two filters were used during the testing procedures – a clear, blank (plano) filter and a bimodal optical (test) filter with a bimodal absorption spectrum (0.25 optical density units). The non-tested eye in each subject was patched and remained patched throughout all testing steps.

Visual acuity

Visual acuity tests were performed in a room with the lights off. The subject was seated and best corrected visual acuity was measured using a Snellen chart at a distance of 20 feet. With the non-tested eye occluded, one of the filters was placed in front of the test eye and visual acuity was measured with the subject reading the Snellen chart. The same procedure was then performed with the other filter. The sequence of the filters tested was randomized and the type of filter used during each test was not known by the subject.

Contrast sensitivity

Contrast sensitivity tests were performed at room lighting. The subject was seated and a Pelli-Robson contrast sensitivity chart was placed at the subject's eye level 1 meter away. The subject was given a +0.75 lens (to compensate for the 1 meter distance) in addition to the subject's own glasses for distance. One of the filters was held together with the +0.75 lens by the subject and placed as close as possible to the glasses. The subject read the letters in each row of the chart until they were unable to do so. Contrast sensitivity was recorded on a separate Pelli-Robson Contrast Sensitivity sheet. The same procedure was then performed with the other filter. The sequence of filters tested was randomized. The type of filter used during each test was not known by the subjects.

Foveal sensitivity

The room lights were turned off and the subject was given 5-7 minutes to dark adapt. The subject's identifying information was put into the Humphrey Visual Field (HVF) machine and 30-2 SITA FAST test was chosen. In order to test foveal sensitivity under scotopic conditions, a 2-log neutral density filter was placed in front of the trial lens holder. Then, a +3.00 diopter lens was placed in the holder along with one of the two filters. The test was explained to the subject, and after the test was performed, the HVF machine calculated foveal sensitivity (performed in triplicate). The same procedure was then performed with the other filter. The sequence of filters tested was randomized. The type of filter used during each test was not known by the subjects. The test was performed in triplicate to obtain reproducible, consistent baseline measurements.

Parafoveal sensitivity

The test on the HFV machine was switched to MACULA FASTPAC or 10-2 SITA FAST. The 2-log neutral density filter, the +3.00 trial lens, and one of the two filters was placed in the holder. The test was explained to the subject, and after the test was performed, the HVF machine calculated sensitivities at each of the appropriate points. The test was performed once for each filter. The sequence of filters tested was randomized. The identity of each filter was not known by the subjects.

Effect of Keeler Indirect Ophthalmoscope with LED Light Source Exposure on Foveal Sensitivity

The subject was given 3-5 minutes to dark adapt after foveal and parafoveal sensitivity testing. The HVF machine was switched back to 30-2 SITA FAST test. A Keeler Vantage Plus LED Wireless Indirect Ophthalmoscope was turned to full power and a small diameter white spot was chosen. One of the filters was held next to the subject's glasses and the light was shined through the filter directly into the subject's eye for 5 seconds from 1 foot away. The patient was asked to fixate on the light source during the exposure. Immediately after, the patient was immediately placed at the HVF machine with the filter, a 2-log neutral density filter, and a +3.00 lens, in the machine for foveal sensitivity tests administered at 0, 1 and 2 minutes post-exposure and every 2 minutes thereafter. After each test was complete, the machine calculated foveal sensitivity. The test was repeated until the foveal sensitivity returned to the baseline measurement for the filter tested. The same procedure was then performed with the other filter. The sequence of filters tested was randomized. The identity of each filter was not known by the subjects.

Effect of Keeler Indirect Ophthalmoscope with LED Light Source Exposure on glare discomfort and photophobia

A Keeler Vantage Plus LED Wireless Indirect Ophthalmoscope was turned to full power and a small diameter white spot was chosen. One of the filters was held next to the subject's glasses and the light was shined through the filter directly into the subject's eye for 3 seconds from 1 foot away. The subject was asked to fixate on the light source during the exposure. The subject was instructed to assume that the amount of glare discomfort felt after the 3-second exposure with the first filter equaled 100%. The identity of each filter was not known by the subjects. The same procedure was then performed with the other filter and the amount of glare discomfort was subjectively compared to that of the first filter. For example, if the second filter was "more comfortable," then the subject would estimate the amount by which it was "more comfortable" (e.g. a 20% reduction in light discomfort was recorded as 80%). Subjective comments were also elicited from the subjects in terms of "why they thought one filter or another was more or less comfortable." When the test filter as described herein was shown first (e.g., corresponding to an initial glare discomfort of 100% according to the test protocol), all glare discomfort data was normalized to the blank filter = 100%, in order to keep data consistent. For example, if the test filter equaled 100% and blank filter equaled 120%, the relative ratio of blank filter to test filter was 1.2, and thus the optical filter would be normalized to 83.3% (e.g., 100/1.2 = 83.3). The amount of glare discomfort for the filters relative to one another was recorded. The sequence of filters tested was randomized. Additionally, participants were asked to complete a de Boer scale to compare the glare discomfort with and without the test filter. See de Boer, J.B. (1967) Visual perception in road traffic and the field of vision of the motorist. In: Public lighting (ed. J.B. de Boer), Philips Technical Library. Eindhoven, The Netherlands, pp.11–96.

Statistics

All statistical analysis was performed using StataCorp. 2011. *Stata Statistical Software: Release 12.* College Station, Tx: StataCorp LP. Statistical significance was accepted at $p < 0.05$.

Results

A total of 17 participants (17 eyes) with subjective symptoms of glare and/or photophobia to headlights during night driving were tested. 11 (64%) right eyes and 6 (35%) left eyes were tested. Males represented 88% and Caucasians 85%. Mean ± SD age was 69.2 ± 8.6 years (range, 51-87 years). Ten (63%) subjects were classified as non-age-related macular degeneration (AMD) with glare and six (37%) subjects as AMD with glare. Mean visual acuity for the non-AMD with glare group was 20/25, and mean visual acuity for the AMD with glare group was 20/31. All testing results were combined for non-AMD with glare and AMD with glare groups due to similarity of group characteristics to facilitate studying the effects of filters on a broad population of patients with symptomatic glare discomfort and photophobia from headlight exposure.

Visual acuity, contrast, foveal, and parafoveal sensitivities

Mean visual acuity with the blank filter (n=15) was 20/31 and 20/30 with the test filter (n=14) (p=0. 56, Mann-Whitney test), indicating that the test filter did not decrease visual acuity relative to the blank. Mean ± SD log contrast sensitivity (n=17) was 1.5 ± 0.15 for the blank filter and 1.48 ± 0.15 for the test filter (p=0.72, Mann-Whitney test), indicating that the test filter did not decrease contrast sensitivity as compared to the blank. Mean ± SD foveal sensitivity (n=51) was 21.8 ± 3.5 decibels (db) for the blank filter and 21.6 ± 3.6 db for the test filter (p=0.95, Mann-Whitney test), indicating that the test filter did not decrease foveal sensitivity as compared to the blank. The mean deviation (± SD) in parafoveal sensitivity (n=17) was -14.1 ± 3.7 db for the blank filter and -14.8 ± 3.8 db for the test filter (p=0.55, Mann-Whitney test), indicating that the bimodal optical filter did not significantly decrease parafoveal sensitivity as compared to the blank.

Physiologic photostress response

When testing physiologic photostress response with the blank filter, 17 (77%) tests had a positive physiologic photostress response (≥2 minutes to recover pre-exposure foveal sensitivity) after a 5 second exposure to the Keeler Vantage Plus LED Wireless Indirect Ophthalmoscope from 1 foot away at full power. When using the test filter, 19 (86%) tests had a physiologic photostress response. The difference in photostress response between the blank and test filters was not statistically significant (p=0.4, Pearson χ^2). Mean ± SD reduction in foveal sensitivity after a 5 second exposure was 4.0 ± 3.8 db with the blank filter and 3.7 ± 4.2 db with the test filter (p=0.56, Mann-Whitney test), indicating that, the loss of foveal sensitivity after light exposure was not significantly reduced by the test filter as compared to the blank.

Mean ± SD time (minutes) to recovery of pre-exposure foveal sensitivity was 4.1 ± 3.0 minutes with the blank filter and 3.8 ± 2.6 minutes with the bimodal optical filter (p=0.93, Mann-Whitney test), indicating that the photostress recovery time was similar with the blank and bimodal filter.

Glare discomfort and photophobia

Mean ± SD (%) comfort improvement vs. blank filter was 18.2 ± 27.7% with the test filter (p=0.0006, Mann-Whitney test). When comparing glare discomfort with the blank filter vs. the test filter with the de Boer scale (1=unbearable glare, 9=unnoticeable glare), the blank filter produced a mean rating of 2.9 ± 2.1, whereas the test filter produced a mean rating of 4.2 ± 1.8

(p=0.038, Mann-Whitney test). These results suggest that glare discomfort was significantly reduced by the bimodal optical filter during light exposure as compared to the blank.

The preceding merely illustrates the principles of the disclosure. All statements herein reciting principles, aspects, and embodiments of the disclosure as well as specific examples thereof, are intended to encompass both structural and functional equivalents thereof. Additionally, it is intended that such equivalents include both currently known equivalents and equivalents developed in the future, e.g., any elements developed that perform the same function, regardless of structure. The scope of the present disclosure, therefore, is not intended to be limited to the exemplary embodiments shown and described herein. Rather, the scope and spirit of present disclosure is embodied by the appended claims.

THAT WHICH IS CLAIMED IS:

1. An optical filter comprising:

an optical substrate; and

a coating on at least a portion of a surface of the optical substrate,

wherein the optical filter is configured to have a multimodal absorption spectrum for reducing glare from glare-producing light.

2. The optical filter of claim 1, wherein the optical filter is configured to have a bimodal absorption spectrum for reducing glare from glare-producing light.

3. The optical filter of claim 1, wherein the absorption spectrum of the optical filter is correlated to an emission spectrum of the glare-producing light.

4. The optical filter of claim 1, wherein the coating has an average light transmittance of 40% to 65% from 400 nm to 420 nm and an average light transmittance of 40% to 65% from 440 nm to 470 nm.

5. The optical filter of claim 1, wherein the coating has an average light transmittance of 40% to 65% from 480 nm to 495 nm.

6. The optical filter of claim 4, wherein the coating comprises a first coating and a second coating on the first coating.

7. The optical filter of claim 1, wherein the coating has an average light transmittance of 70% or more from 420 nm to 440 nm.

8. The optical filter of claim 1, wherein the coating has an average light transmittance of 90% or more at wavelengths of 500 nm or greater.

9. The optical filter of claim 1, wherein the coating comprises a metal oxide.

10. The optical filter of claim 1, wherein the coating covers 85% or less of the surfaces of the optical substrate.

11. The optical filter of claim 1, wherein the coating has a decreasing gradient-thickness.

12. The optical filter of claim 1, wherein the optical substrate is a lens for spectacles, contact lenses, intraocular lenses, clip-on glasses, fitovers, or goggles, or a headlight lens or cover.

13. The optical filter of claim 1, wherein the optical substrate is a lens, a window or a cover for a lens or a window.

14. The optical filter of claim 13, wherein the window is an automotive windshield.

15. The optical filter of claim 1, wherein the glare-producing light is from a glare-producing light source selected from the group consisting of a high-intensity discharge headlight, a light-emitting diode headlight and a metal-halide light.

16. The optical filter of claim 1, wherein the optical filter is configured to reduce glare from a glare-producing light source without significantly decreasing visual function in a subject.

17. An article of eyewear comprising:
a lens; and
a coating on at least a portion of a surface of the lens,
wherein the article of eyewear is configured to have a multimodal absorption spectrum for reducing glare from glare-producing light.

18. The article of eyewear of claim 17, wherein the article of eyewear is configured to have a bimodal absorption spectrum for reducing glare from glare-producing light.

19. The article of eyewear of claim 17, wherein the lens is a corrective lens.

20. The article of eyewear of claim 17, wherein the lens is a non-corrective lens.

21. The article of eyewear of claim 17, wherein the lens is a lens for spectacles, contact lenses, intraocular lenses, clip-on glasses, fitovers, or goggles.

22. A method of reducing glare from a glare-producing light source, the method comprising:

positioning an optical filter between the glare-producing light source and a subject, the optical filter comprising:

an optical substrate; and

a coating on at least a portion of a surface of the optical substrate,

wherein the optical filter is configured to have an absorption spectrum that is correlated to the emission spectrum of the glare-producing light source at wavelengths of 500 nm or less.

23. The method of claim 22, further comprising selecting the optical filter such that the optical filter is configured to have an absorption spectrum that is correlated to the emission spectrum of the glare-producing light source at wavelengths of 500 nm or less.

24. The method of claim 22, wherein the optical filter is configured to have a multimodal absorption spectrum for glare-producing light from the glare-producing light source.

25. The method of claim 22, wherein the optical filter is configured to have a bimodal absorption spectrum for glare-producing light from the glare-producing light source.

26. The method of claim 22, wherein the optical filter has an optical density such that the optical filter is configured to reduce glare from the glare-producing light source without causing a significant decrease in visual function.

27. The method of claim 22, wherein the optical filter has an optical density such that the optical filter is configured to reduce glare from the glare-producing light source without causing a significant decrease in visual function in conditions of reduced illumination.

28. The method of claim 22, wherein the subject has been diagnosed with age-related macular degeneration.

29. The method of claim 22, wherein the glare-producing light source is a high-intensity discharge headlight, a light-emitting diode headlight or a metal-halide light.

30. The method of claim 22, wherein the optical filter is configured to reduce glare from the glare-producing light source in left-sided oncoming traffic.

31. A method of producing an optical filter, the method comprising:

contacting at least a portion of a surface of an optical substrate with a coating configured to have an absorption spectrum that is correlated to the emission spectrum of a glare-producing light source at wavelengths of 500 nm or less to produce an optical filter.

32. The method of claim 31, wherein the optical filter is configured to have a bimodal absorption spectrum for glare-producing light from the glare-producing light source.

33. The method of claim 31, wherein the contacting comprises directing an evaporated metal and an ion source towards the surface of the optical substrate.

34. The method of claim 31, wherein the method further comprises cooling the optical substrate.

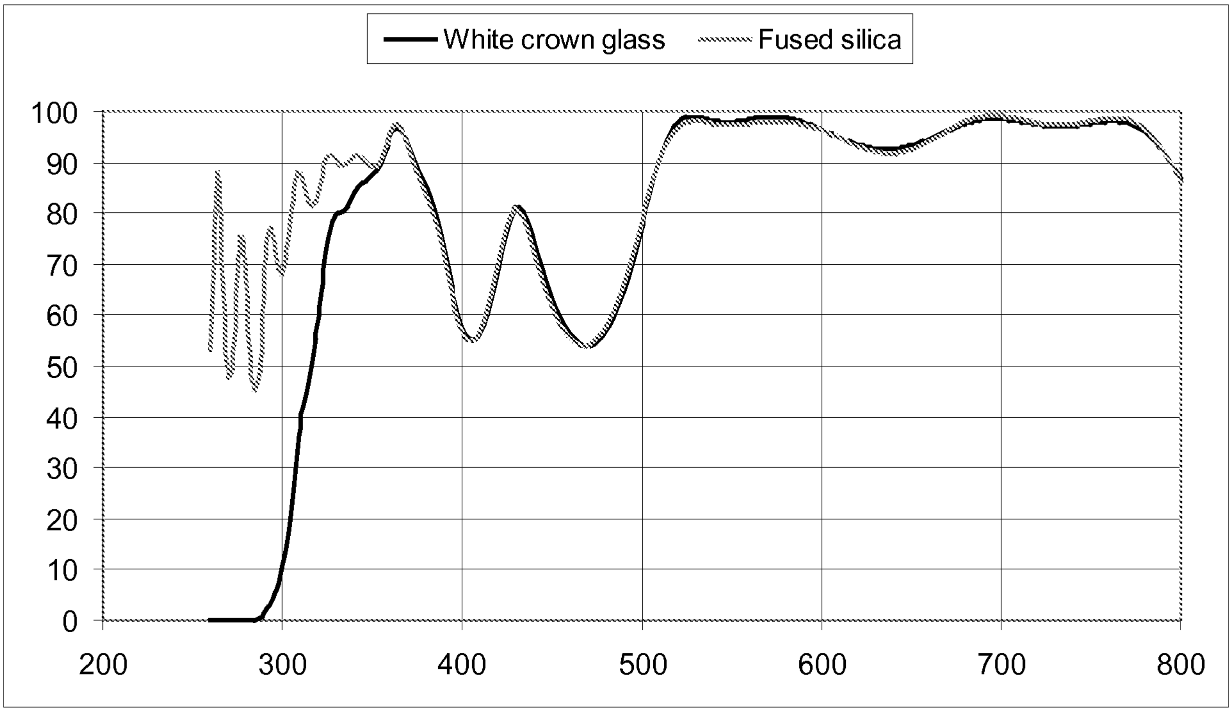
White crown glass
Fused silica
100
90
80
70
60
50
40
30
20
10
0
200
300
400
500
600
700
800

FIG. 1

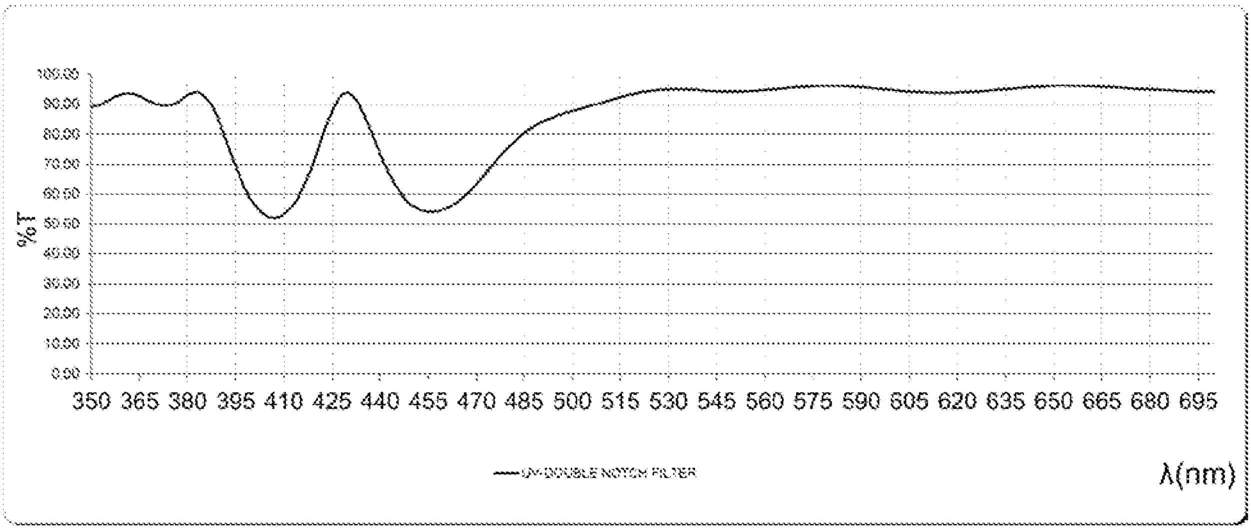
100.00
90.00
80.00
70.00
60.00
50.00
40.00
30.00
20.00
10.00
0.00
%T
350 365 380 395 410 425 440 455 470 485 500 515 530 545 560 575 590 605 620 635 650 665 680 695
UV-DOUBLE NOTCH FILTER
λ(nm)

FIG. 2

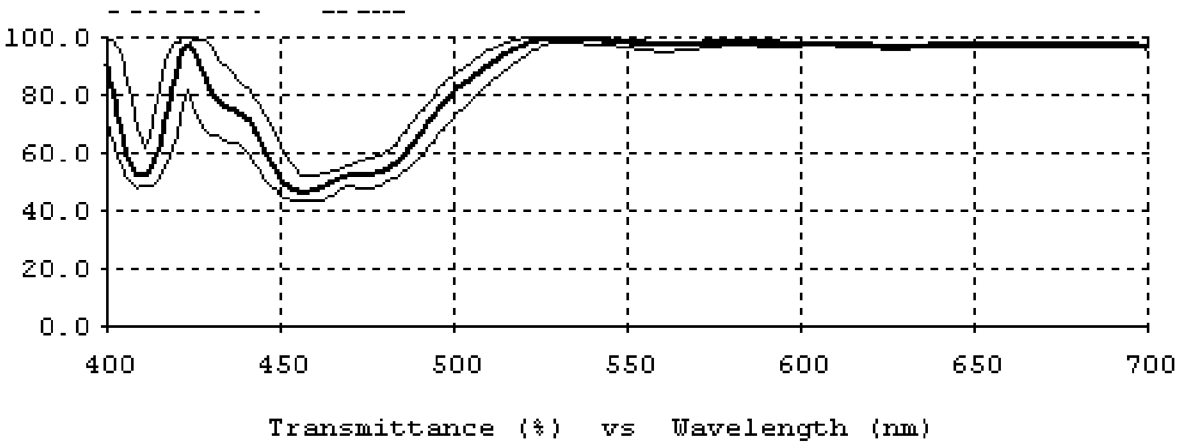
100.0
80.0
60.0
40.0
20.0
0.0
400
450
500
550
600
650
700
Transmittance (%) vs Wavelength (nm)

FIG. 3

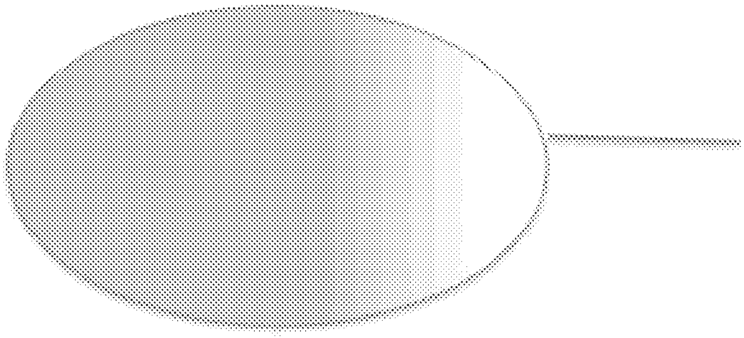

FIG. 4

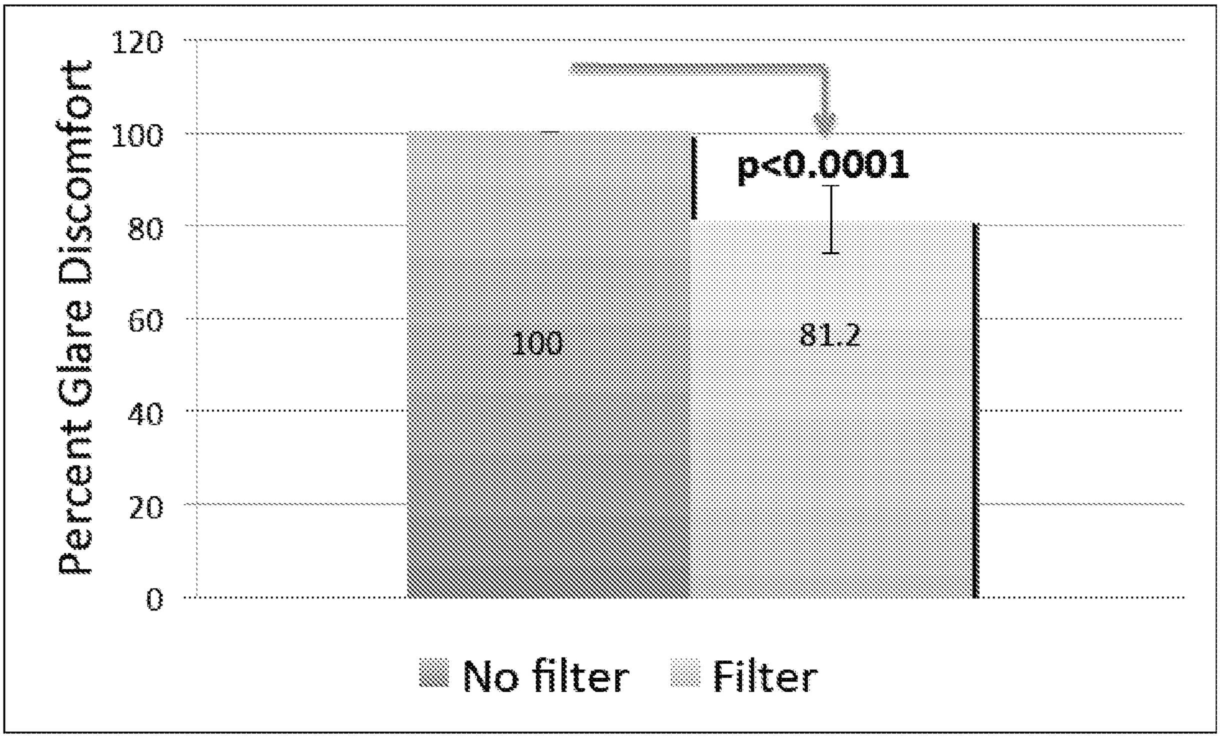
Percent Glare Discomfort
120
100
80
60
40
20
0
p<0.0001
100
81.2
No filter
Filter

FIG. 5

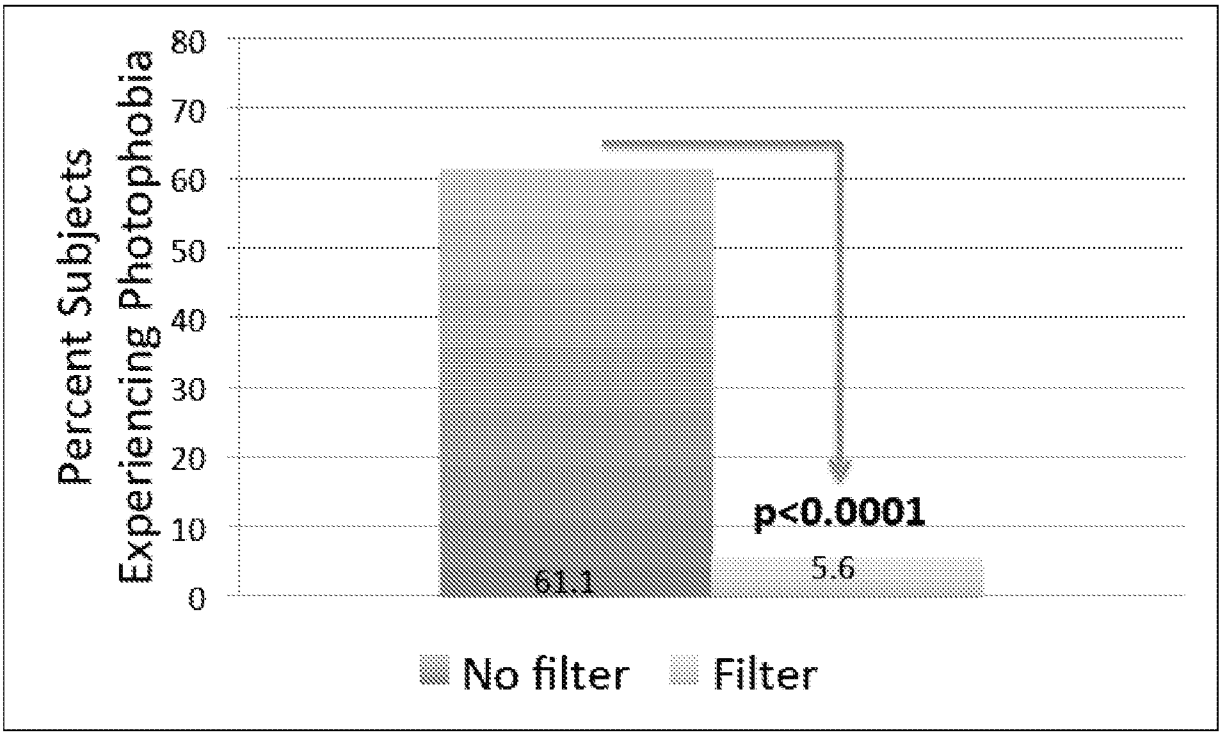
Percent Subjects
Experiencing Photophobia
80
70
60
50
40
30
20
10
0
61.1
5.6
p<0.0001
No filter
Filter

FIG. 6

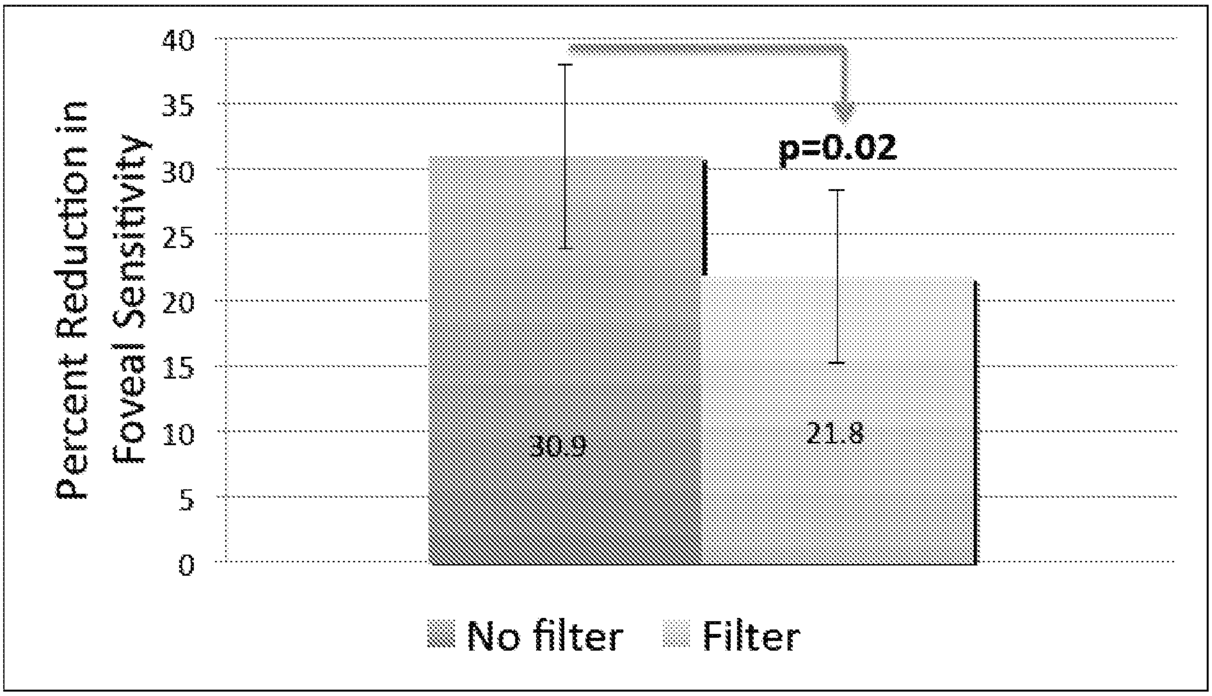
Percent Reduction in Foveal Sensitivity
40
35
30
25
20
15
10
5
0
p=0.02
30.9
21.8
No filter
Filter

FIG. 7

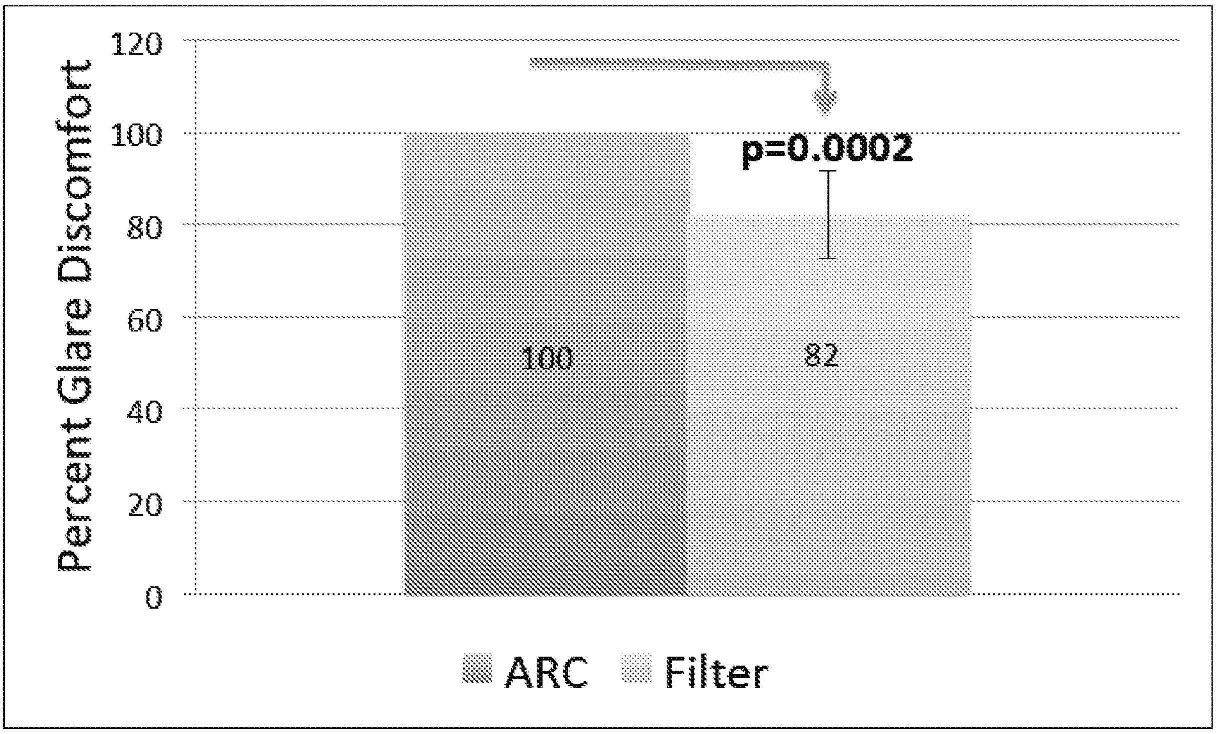
Percent Glare Discomfort
120
100
80
60
40
20
0
p=0.0002
100
82
ARC
Filter

FIG. 8

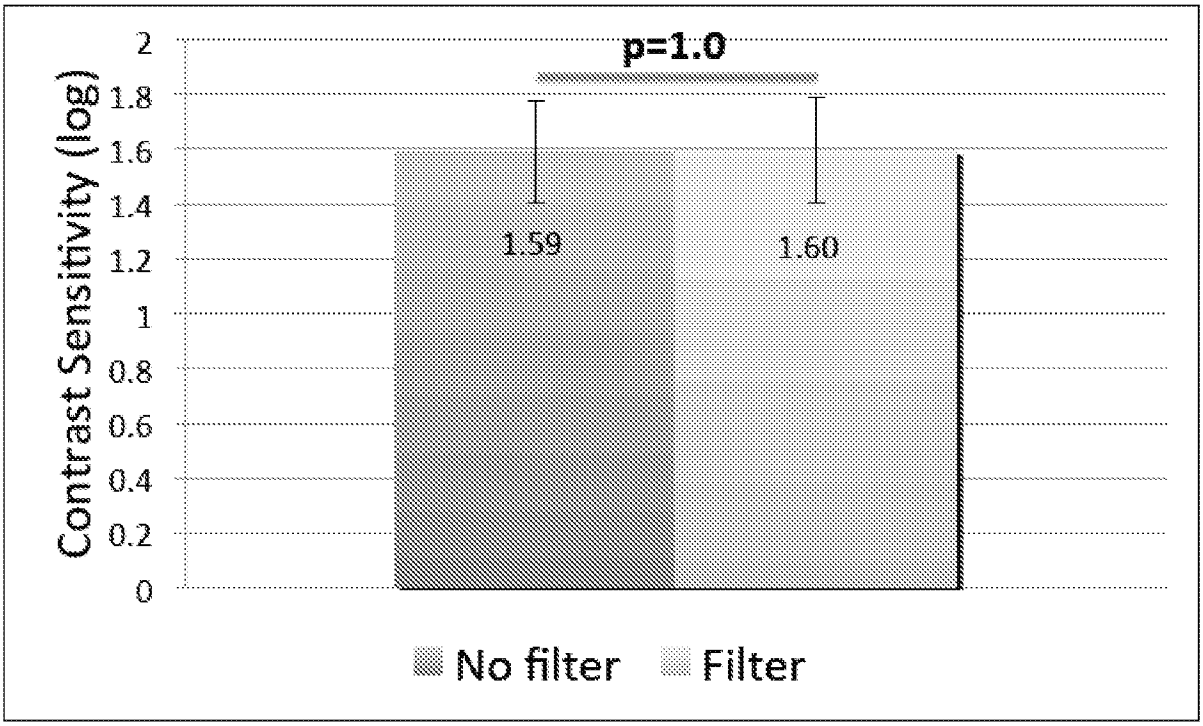
Contrast Sensitivity (log)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
p=1.0
1.59
1.60
No filter
Filter

FIG. 9

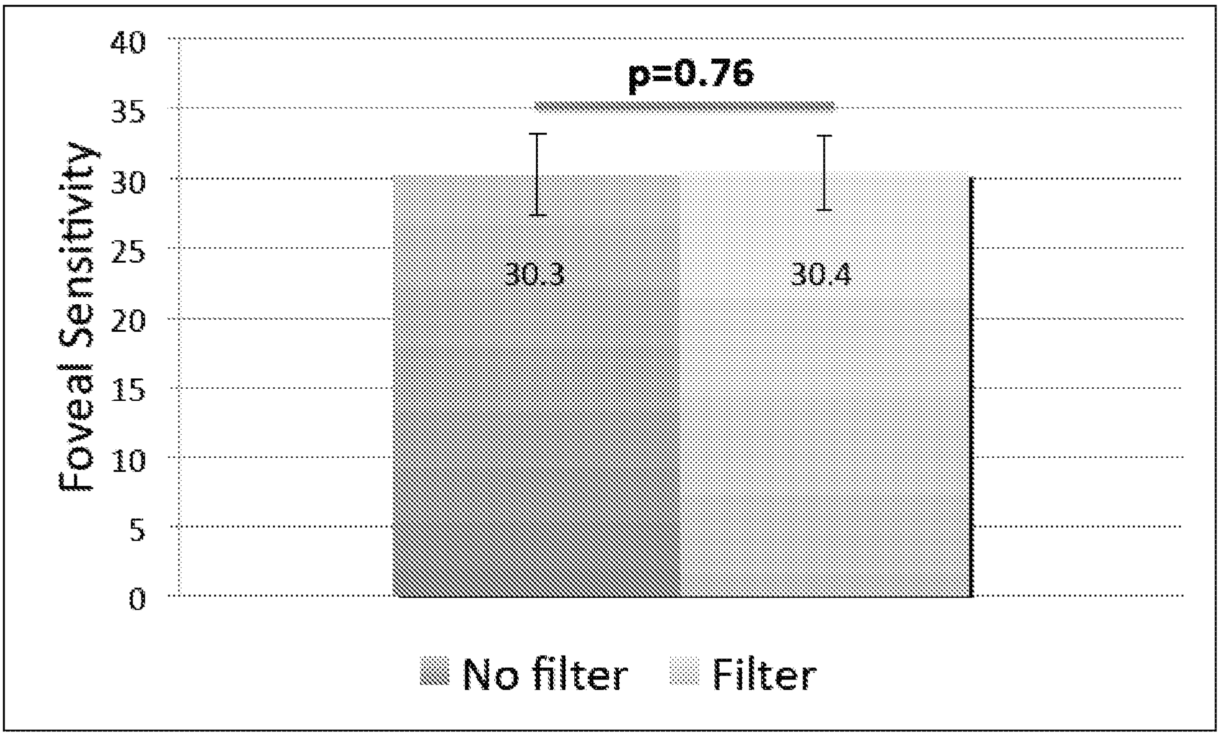
40
35
30
25
20
15
10
5
0
Foveal Sensitivity
p=0.76
30.3
30.4
No filter
Filter

FIG. 10

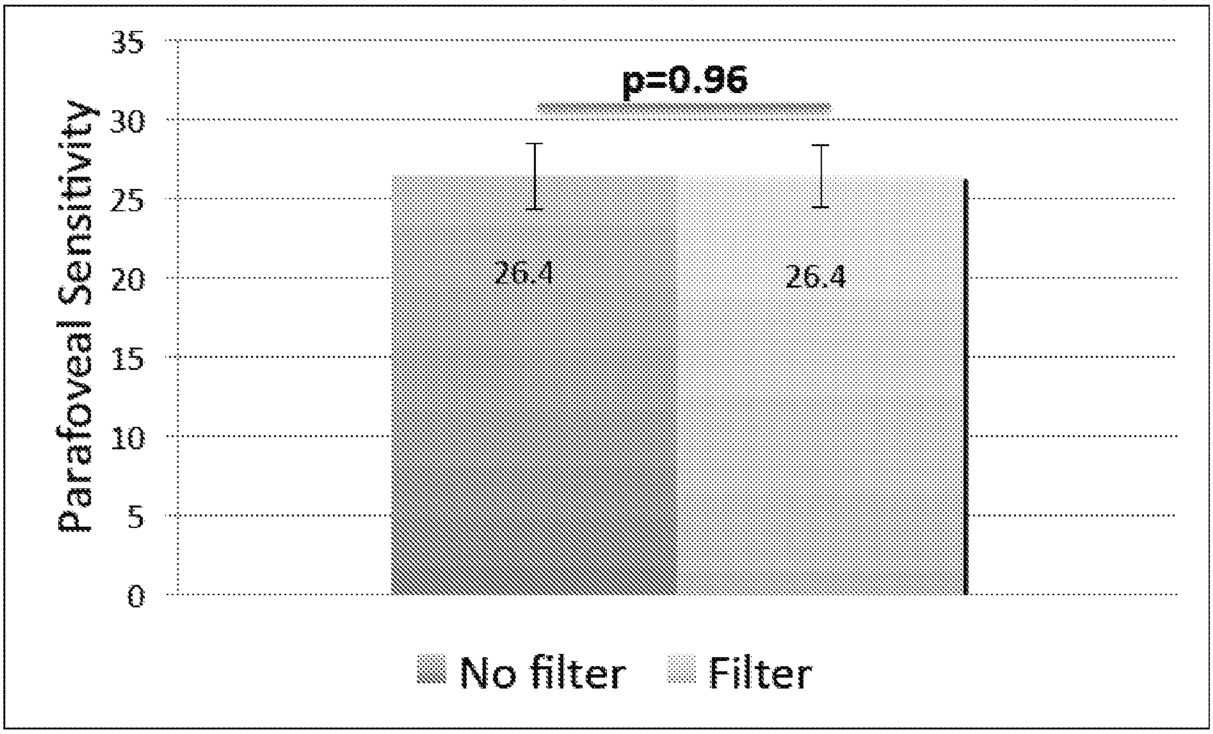
Parafoveal Sensitivity
35
30
25
20
15
10
5
0
p=0.96
26.4
26.4
No filter
Filter

FIG. 11

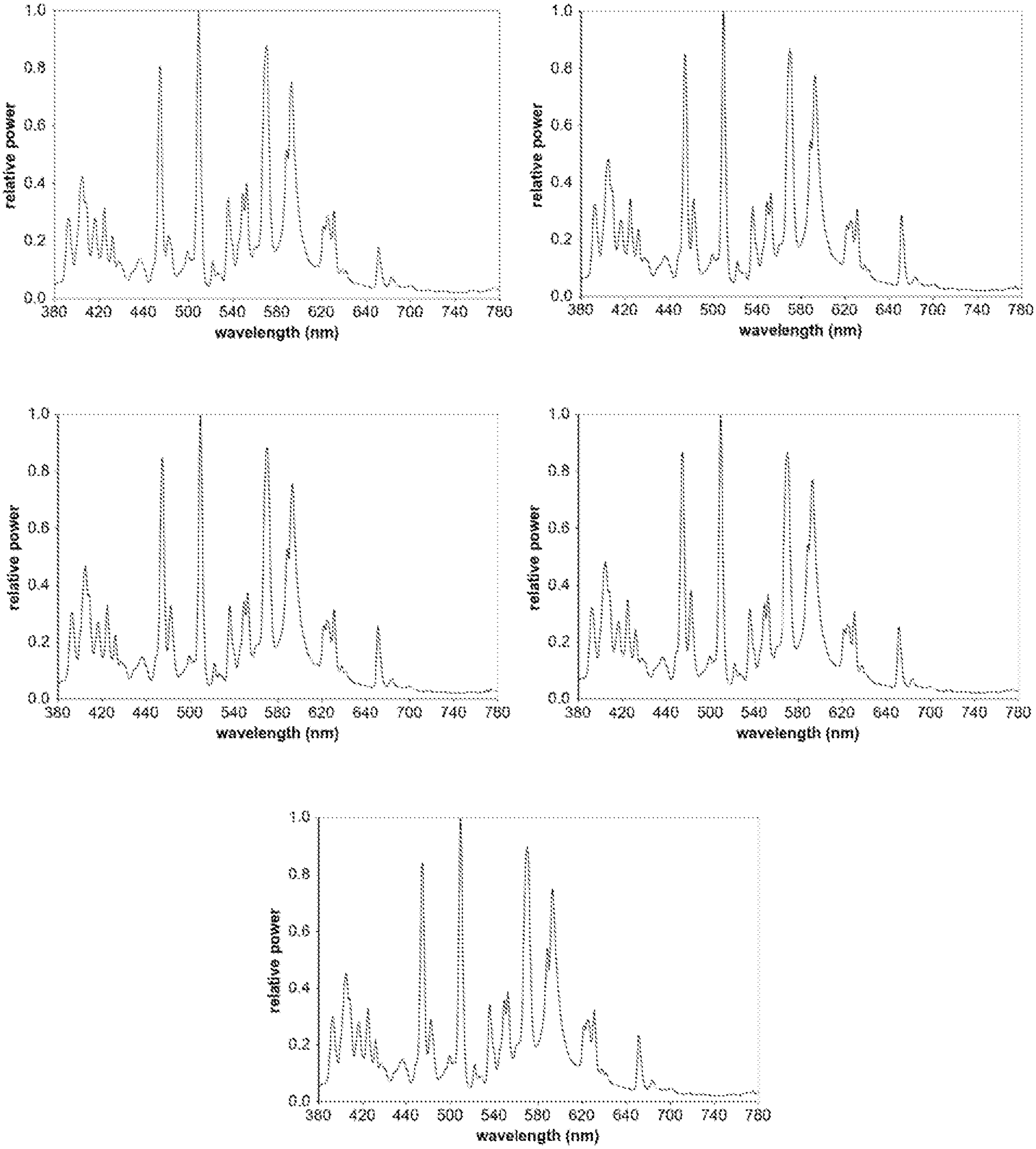
1.0
0.8
0.6
0.4
0.2
0.0
relative power
380 420 440 500 540 580 620 640 700 740 780
wavelength (nm)

FIG. 12

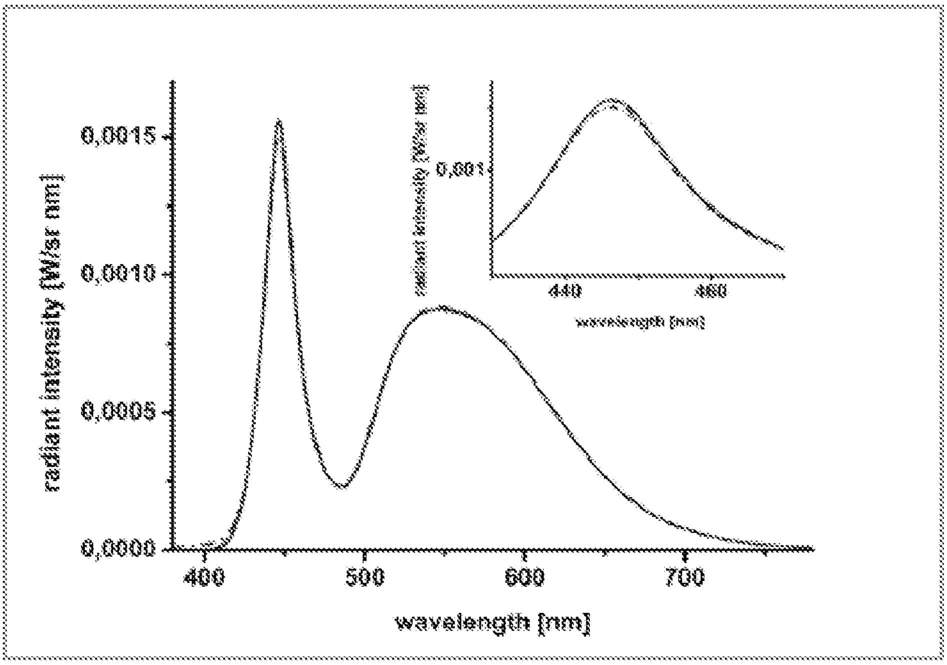
radiant intensity [W/sr nm]
0,0015
0,0010
0,0005
0,0000
400
500
600
700
wavelength [nm]
radiant intensity [W/sr nm]
0,001
440
460
wavelength [nm]

FIG. 13

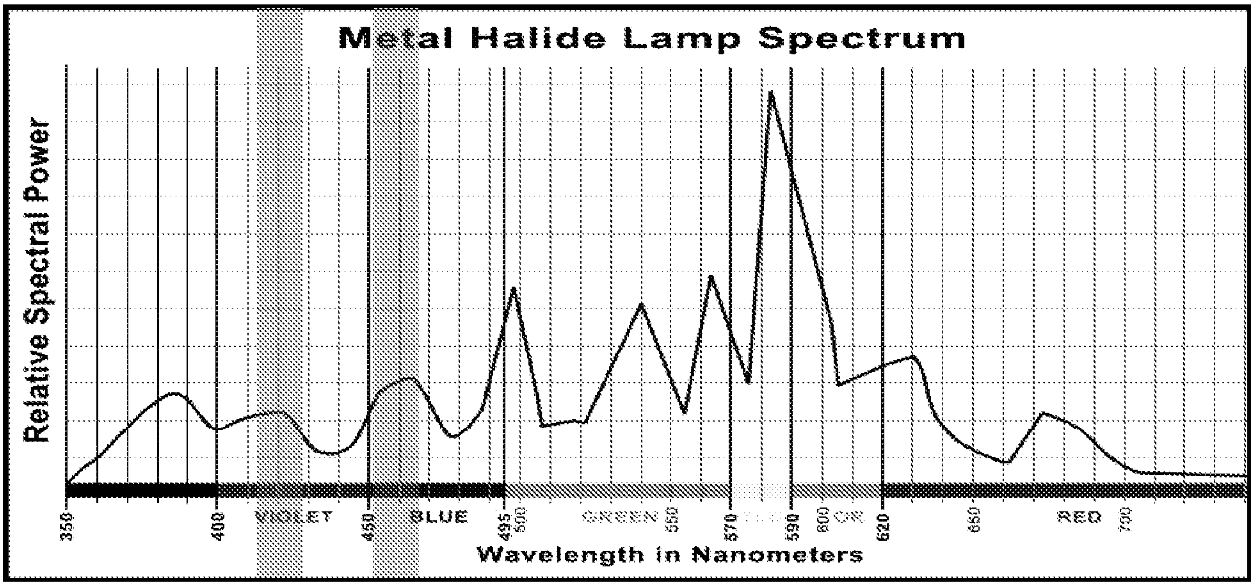
Metal Halide Lamp Spectrum
Relative Spectral Power
350
400
VIOLET
450
BLUE
495
500
GREEN
550
570
590
600
OR
620
650
RED
700
Wavelength in Nanometers

FIG. 14

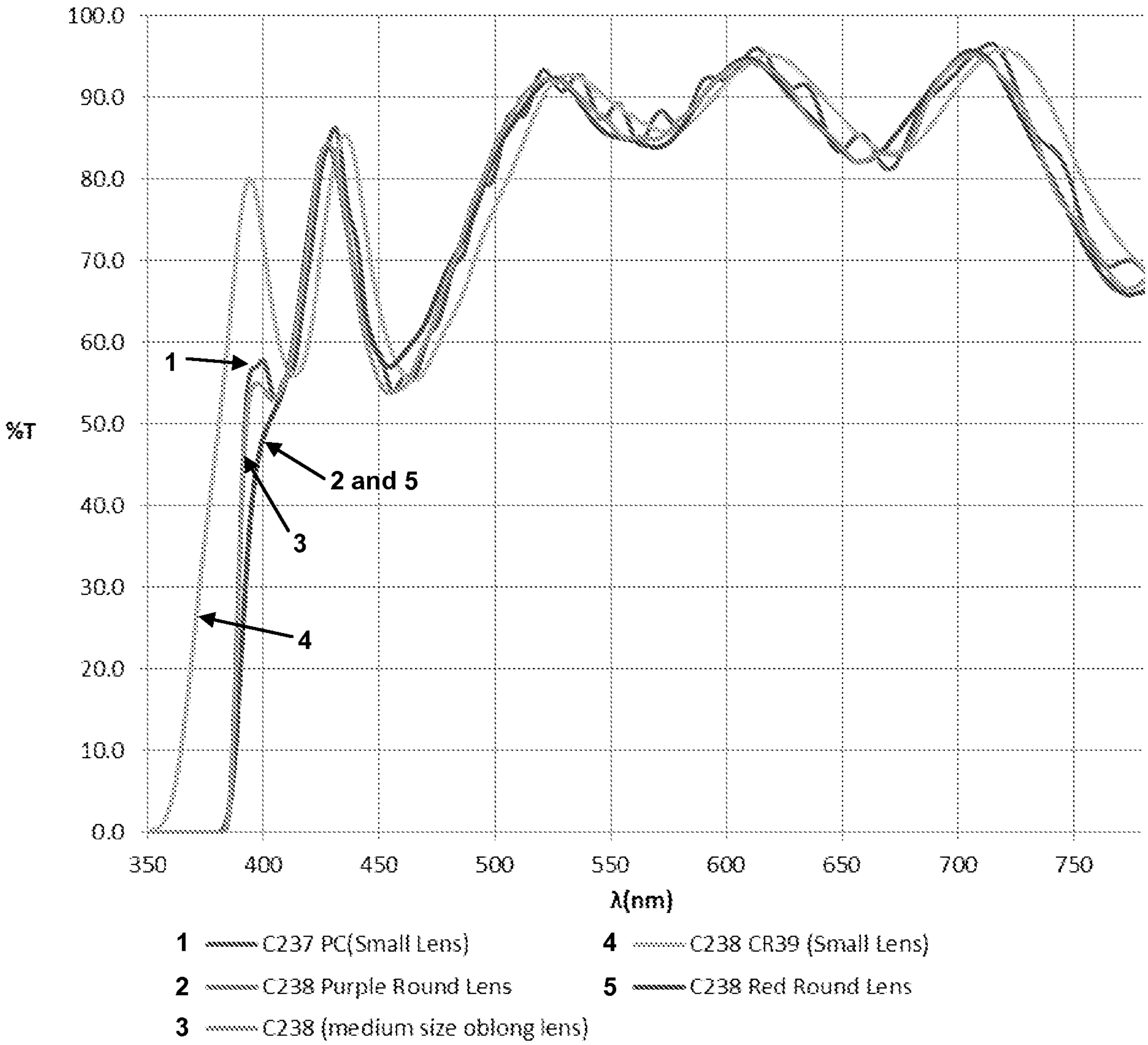
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
%T
350
400
450
500
550
600
650
700
750
λ(nm)
1
2 and 5
3
4
1 C237 PC(Small Lens)
2 C238 Purple Round Lens
3 C238 (medium size oblong lens)
4 C238 CR39 (Small Lens)
5 C238 Red Round Lens

FIG. 15

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/045986

A. CLASSIFICATION OF SUBJECT MATTER
IPC(8) - G02B 5/30 (2013.01)
USPC - 359/489.19
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC(8) - G02B 5/30, 27/28; G02C 7/10, 7/12 (2013.01)
USPC - 359/489.18, 489.19, 484.09; 351/44, 49, 159.01

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
CPC - G02B 5/3083, 27/288, 27/46 (2013.01)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
Orbit, Google Patents, ProQuest

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2010/0149483 A1 (CHIAVETTA, III) 17 June 2010 (17.06.2010) entire document	1-3, 5, 9-10, 12-14, 16-27, 31-32
Y		4, 6-8, 11, 15, 28-30, 33-34
Y	US 2009/0189832 A1 (LEE et al) 30 July 2009 (30.07.2009) entire document	4, 6
Y	US 2012/0008217 A1 (ISHAK et al) 12 January 2012 (12.01.2012) entire document	7
Y	US 2008/0277606 A1 (WANG et al) 13 November 2008 (13.11.2008) entire document	8
Y	US 2002/0186474 A1 (WEBER et al) 12 December 2002 (12.12.2002) entire document	11
Y	US 2004/0178367 A1 (FISCHER, JR. et al) 16 September 2004 (16.09.2004) entire document	15, 29
Y	US 2011/0141437 A1 (JACKSON et al) 16 June 2011 (16.06.2011) entire document	28
Y	EP 0533508 A2 (BEN-LULU) 24 March 1993 (24.03.1993) entire document	30
Y	US 2008/0094840 A1 (WU) 24 April 2008 (24.04.2008) entire document	33-34
A	US 7,025,908 B1 (HAYASHI et al) 11 April 2006 (11.04.2006) entire document	1-34

☒ Further documents are listed in the continuation of Box C. ☐

* Special categories of cited documents:
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"E" earlier application or patent but published on or after the international filing date
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"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search
31 October 2013

Date of mailing of the international search report
08 NOV 2013

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INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2013/045986

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2006/0092374 A1 (ISHAK) 04 May 2006 (04.05.2006) entire document	1-34
A	US 2004/0114242 A1 (SHARP) 17 June 2004 (17.06.2004) entire document	1-34