ELECTRO-SWITCHABLE SPECTACLES FOR MYOPIA TREATMENT

RELATED APPLICATIONS

[0001] This application claims the benefit under 35 U.S.C. § 119(e) of U.S. Provisional Patent Application No. 63/024,379, filed May 13, 2020, and titled "ELECTRO-SWITCHABLE SPECTACLES FOR MYOPIA TREATMENT," which is incorporated, in its entirety, by this reference.

[0002] The subject matter of the present application is related to PCT/US2020/044571, filed on July 31, 2020, entitled "DEVICE FOR PROJECTING IMAGES ON THE RETINA", published as WO/2021/022193 on February 4, 2021, the entire disclosure of which is incorporated herein by reference.

BACKGROUND

[0003] Work in relation to the present disclosure suggests that myopically defocused light to the peripheral retina can decrease the progression of myopia. However, at least some of the prior approaches can be less than ideal in at least some respects. For example, at least some of the prior approaches can be more complex than would be ideal and may provide less than ideal treatment results. Also, at least some of the prior approaches can degrade vision more than would be ideal.

[0004] In light of the above, improved methods and apparatus for treating refractive error that ameliorate at least some of the limitations of the prior approaches are needed.

SUMMARY

[0004a] In a first aspect, the present disclosure provides an apparatus to treat refractive error of an eye, the apparatus comprising: a lens comprising an optical zone; and a switchable zone extending around the optical zone, wherein the switchable zone comprises an electroactive material switchable between a first configuration to substantially scatter or defocus light and second configuration to substantially transparently transmit light through the lens

[0005] In some embodiments, an apparatus to treat refractive power of one or both eyes such as an eyeglass optic comprises a lens to correct refractive power and a switchable optical component. The switchable optical component can be configured with an electroactive material to provide optical power or light scattering to treat refractive error of the eye. The switchable optical component can be configured to turn on and off manually or automatically using an electronic control system. In an off state, the

additional optical component functions as a substantially transparent optical layer with no substantial optical power or light scattering. In an on state, the optical component is either switched to a fixed or controllable amount of optical power, or a fixed or controllable amount of light scatter. In some embodiments, the switchable component comprises an electro-active optic comprising a plurality of optical elements, such as pixels. In some embodiments, the electro-active optical component comprises a

CLAIMS

WHAT IS CLAIMED IS:

1. An apparatus to treat refractive error of an eye, the apparatus comprising:

a lens comprising an optical zone; and

a switchable zone extending around the optical zone, wherein the switchable zone comprises an electroactive material switchable between a first configuration to substantially scatter or defocus light and second configuration to substantially transparently transmit light through the lens.

2. The apparatus of claim 1, wherein the switchable zone is substantially translucent in the first configuration and substantially transparent in the second configuration.

3. The apparatus of claim 1, wherein images viewed through the switchable zone in the first configuration appear blurry.

4. The apparatus of claim 1, wherein an optical power of the optical zone remains substantially fixed for the first configuration and the second configuration of the switchable zone.

5. The apparatus of claim 3, wherein the switchable zone comprises particles to blur the viewed images in response to a difference between an index of refraction of the particles and the electroactive material.

6. The apparatus of claim 3, wherein switchable zone comprises a liquid crystal material configured to vary an optical power of the switchable zone and wherein the optical power in the first configuration differs from an optical power of the second configuration.

7. The apparatus of claim 6, wherein the switchable zone comprises a plurality of switchable lenslets to vary the optical power, the plurality switchable lenslets comprising one or more of an optical surface profile or an electrode profile to vary the optical power and defocus light in the first configuration.

8. The apparatus of claim 3, wherein the switchable zone comprises one or more optical structures comprising an optical surface profile to blur the viewed images in response to a difference between an index of refraction of the one or more optical structures and an index of refraction of the electroactive material.

9. The apparatus of claim 8, wherein the optical surface profile comprises a diffractive optic profile to provide optical power in response to the difference in the index of refraction of the one or more optical structures and the index of refraction of the electroactive material.

10. The apparatus of claim 9, wherein the diffractive optic profile comprises a plurality of echelletes.

11. The apparatus of claim 9, wherein switchable zone is configured to focus an image of an object anterior or posterior to the retina in the first configuration and to focus the image of the object onto the retina in the second configuration.

12. The apparatus of claim 3, wherein the switchable zone comprises an electrode profile to blur the viewed images with diffraction in response to a difference between a first index of refraction of the electroactive material at first location and a second index of refraction of the electroactive material at a second location, the first location closer to the electrode than the second location.

13. The apparatus of claim 12, wherein electrode profile is configured to provide optical power to the switchable zone to focus light away from the retina in the first configuration.

14. The apparatus of claim 13, wherein electrode profile is configured to generate positive optical power and negative optical power with diffraction related to the difference between the first index at the first location and the second index at the second location.

15. The apparatus of claim 12, wherein electrode profile comprises a plurality of gaps corresponding to the second location of the electroactive material.

16. The apparatus of claim 15, wherein electrode profile comprises an electrode trace extending along a substrate corresponding to the first location of the

electroactive material and wherein the electrode profile comprises a plurality of gaps defined by the traces of the electrode

17. The apparatus of claim 16, wherein the second location of the electroactive material comprises a plurality of second locations and wherein the plurality of gaps corresponds to the plurality of second locations of the electroactive material.

18. The apparatus of claim 1, wherein the lens comprises an optical power, the optical zone comprising the optical power and wherein the switchable zone is located on the lens to transmit light with the optical power in the second configuration.

19. The apparatus of claim 18, wherein the lens comprises a first side and a second side, the switchable zone located on the first side, the second side comprising a curvature to provide a majority of the optical power of the lens.

20. The apparatus of claim 1, wherein the switchable zone comprises the first configuration when a voltage is applied to the zone and the second configuration without the voltage applied to the zone.

~~21. The apparatus of claim 1, wherein the switchable zone comprises the second configuration when a voltage is applied to the zone and the first configuration without the voltage applied to the zone.~~

~~22. The apparatus of claim 1, wherein switchable zone comprises an annular zone.~~

~~23. The apparatus of claim 1, wherein the optical zone comprises a central optical zone.~~

~~24. The apparatus of claim 1, wherein the switchable zone is located on a portion of the lens configured to correct the refractive error of the eye.~~

~~25. The apparatus of claim 1, wherein the optical zone is configured to correct a refractive error of the eye.~~

~~26. The apparatus of claim 1, wherein the optical zone is sized to transmit light at an angle within range from 12 degrees to 20 degrees with reference to an entrance pupil of the eye.~~

~~27. The apparatus of claim 25, wherein the angle is within a range from 14 to 16 degrees.~~

~~28. The apparatus of claim 25, wherein the angle comprises a half-angle.~~

~~29. The apparatus of claim 1, wherein the switchable zone is sized to transmit light at an angle within range from 15 degrees to 50 degrees with reference to an entrance pupil of the eye.~~

~~30. The apparatus of claim 28, wherein the switchable zone comprises an inner boundary and an outer boundary, the inner boundary corresponding to an inner angle within a range from 15 degrees to 20 degrees with reference to the entrance pupil of the eye, the outer boundary corresponding to an outer angle within a range from 25 degrees to 50 degrees with reference to the entrance pupil of the eye.~~

~~31. The apparatus of claim 29, wherein the lens is mounted on an eyeglass frame to provide a vertex distance to a cornea of the eye, the vertex distance, the inner boundary and the outer boundary dimensioned to provide the inner angle and the outer angle with reference to the entrance pupil of the eye.~~

~~32. The apparatus of claim 1, wherein switchable zone comprises a liquid crystal material and particles within the liquid crystal material and wherein the particles scatter light a greater amount of in the first configuration than in the second configuration.~~

~~33. The apparatus of claim 31, wherein particles comprise microspheres.~~

~~34. The apparatus of claim 31, wherein particles comprise a diameter within a range from 1 micron to 1000 microns and optionally within a range from 5 microns to 500 microns and optionally within a range from 10 microns to 250 microns.~~

~~35. The apparatus of claim 31, wherein the particles comprise a maximum distance across within a range from 1 micron to 1000 microns and optionally within a range from 5 microns to 500 microns and optionally within a range from 10 microns to 250 microns.~~

~~36. The apparatus of claim 31, wherein the particles comprise a size distribution with a majority of particles at least 5 microns across and no more than 500 microns across and optionally at least 10 microns and no more than 250 microns and optionally wherein the particles comprise spheres and the dimensions comprise diameters.~~

~~37. The apparatus of claim 31, wherein the particles comprise a distribution of particle sizes configured to scatter light into an entrance pupil of the eye with a first amount at 400 nm and a second amount at 750 nm, the first amount within 25% of the second amount.~~

~~38. The apparatus of claim 36, wherein the distribution of particles is configured to scatter light substantially uniformly over a range of wavelengths from 400 nm to 750 nm and wherein an amount of scatter over the range varies no more than about 25%.~~

~~39. The apparatus of claim 31, wherein the liquid crystal material comprises a refractive index within a range from 1.5 to 1.65 and wherein the liquid crystal material is configured to change the refractive index by an amount within a range from 0.10 to 0.25.~~

~~40. The apparatus of claim 31, wherein the particles comprise a refractive index within a range from 1.5 to 1.7 and optionally wherein the refractive index corresponds to the sodium D line at approximately 589 nm.~~

~~41. The apparatus of claim 31, wherein the particles comprise one or more of ion doped glasses, polyacrylates, polymethacrylates, polyaromatics, polysulfones, polyimides, polyamides, polyethers, polyether ketones, or polycyclic olefins.~~

~~42. The apparatus of claim 31, wherein the liquid crystal material is switchable from a first refractive index in the first configuration to substantially scatter light to a second refractive index in the second configuration to substantially transparently transmit light and wherein the second refractive index is closer to a refractive index of the particles to decrease light scatter from the particles in the second configuration.~~

~~43. The apparatus of claim 41, wherein the first refractive index differs from the refractive index of the particles by at least 0.05 to substantially scatter light and the~~

second refractive index differs from the refractive index of the particles by no more than 0.02 to substantially transparently transmit light.

44. The apparatus of claim 31, wherein the liquid crystal material is configured to provide a change in refractive index within a range from 0.10 to 0.25.

45. The apparatus of claim 31, wherein the liquid crystal material comprises a transparent material with a glass transition temperature below -10 degrees C and a melting point above 100 degrees C and optionally wherein the liquid crystal material comprises one or more of a nematic phase, a cholesteric phase or smectic phase.

46. The apparatus of claim 1, wherein the switchable zone comprises:

an adhesive layer;

a scratch resistant layer; and

a switchable layer between the adhesive layer and the scratch resistant layer, the switchable layer comprising a liquid crystal material and one or more of particles, an optical surface profile or an electrode profile.

47. The apparatus of claim 45, wherein the adhesive layer is adhered to the lens.

48. The apparatus of claim 45, wherein the adhesive layer, the scratch resistant layer and the switchable layer comprise a combined thickness within a range from 0.1 mm to 2 mm and optionally within a range from 0.1 mm to 1 mm.

49. The apparatus of claim 45, wherein the scratch resistant layer comprises a thickness within a range from 10 microns to 100 microns, the adhesive layer comprises a thickness within a range from 10 microns to 100 microns and the switchable layer comprises a thickness within a range from 25 microns to 1000 microns.

50. The apparatus of claim 45, wherein the scratch resistant layer comprises a substantially transparent electrode oriented toward the switchable layer and the adhesive layer comprises a substantially transparent electrode oriented toward the switchable layer.

51. The apparatus of claim 49, wherein each of the substantially transparent electrodes comprises a thickness within a range from 25 to 250 Angstroms and optionally

~~wherein each of the substantially transparent electrodes comprises and indium tin oxide (ITO) electrode.~~

~~52. The apparatus of claim 1, further comprising a power source to apply a voltage to the switchable zone and optionally wherein the power source comprises a rechargeable battery.~~

~~53. The apparatus of claim 1, further comprising circuitry coupled to the switchable zone to control a configuration of the switchable zone, the circuitry comprising one or more of a processor, a microcontroller, a sensor or logic circuitry to control the configuration of the switchable zone and optionally wherein the switchable zone comprises the first configuration of the second configuration in response to inputs to the circuitry.~~

~~54. The apparatus of claim 52, wherein the circuitry is configured to vary an amount of light scatter of the switchable zone to vary an amount of substantially scattered light and optionally wherein the first configuration comprises a plurality of configurations each configured to scatter a different amount of light.~~

~~55. The apparatus of claim 52, wherein the circuitry is configured to vary an amount of optical power of the switchable zone and optionally wherein the first configuration comprises a plurality of configurations each configured to provide a different amount of optical power.~~

~~56. The apparatus of claim 1, wherein the electroactive material comprises a liquid crystal material, the liquid crystal material comprising a refractive index within a range from 1.5 to 1.65 and wherein the liquid crystal material is configured to change the refractive index by an amount within a range from 0.10 to 0.25.~~

~~57. The apparatus of claim 1, wherein the switchable zone comprises one or more of an optical surface profile or an electrode profile on a surface of a substantially transparent substrate material.~~

~~58. The apparatus of claim 56, wherein the substrate material comprises a refractive index within a range from 1.5 to 1.7 and optionally wherein the refractive index corresponds to the sodium D line at approximately 589 nm.~~

59. The apparatus of claim 56, wherein the substrate material comprises one or more of ion doped glasses, polyacrylates, polymethacrylates, polyaromatics, polysulfones, polyimides, polyamides, polyethers, polyether ketones, or polycyclic olefins.

60. The apparatus of claim 56, wherein the liquid crystal material is switchable from a first refractive index in the first configuration to provide optical power to a second refractive index in the second configuration to substantially transparently transmit light through the substrate material and wherein the second refractive index is closer to a refractive index of the substrate material in the second configuration.

61. The apparatus of claim 59, wherein the first refractive index differs from the refractive index of the substrate material by at least 0.05 to provide optical power and the second refractive index differs from the refractive index of the substrate material by no more than 0.02 to substantially transparently transmit light.

62. The apparatus of claim 56, wherein the liquid crystal material is configured to provide a change in refractive index within a range from 0.10 to 0.25.

63. The apparatus of claim 56, wherein the liquid crystal material comprises a transparent material with a glass transition temperature below -10 degrees C and a melting point above 100 degrees C and optionally wherein the liquid crystal material comprises one or more of a nematic phase, a cholesteric phase or smectic phase.

64. An electroactive component for use with a lens to treat refractive error of an eye, the electroactive component comprising:

an adhesive layer configured to adhere to a lens;

a scratch resistant layer; and

a switchable layer between the adhesive layer and the scratch resistant layer, the switchable layer comprising a liquid crystal material and one or more of particles, an optical surface profile or an electrode profile.

65. The electroactive component of claim 63, wherein the switchable layer does not extend over a central portion sized and shaped to provide an optical zone on the lens.

~~66. The electroactive component of claim 63, further comprising circuitry coupled to the switchable zone to control a configuration of the switchable zone, the circuitry comprising one or more of a processor, a microcontroller, a sensor or logic circuitry to control the configuration of the switchable zone and optionally wherein the switchable zone comprises the first configuration of the second configuration in response to inputs to the circuitry.~~