difference / Average luminance. Experiments demonstrate that this amount of reduction in contrast has significant effects on the physiology of the eye related to mechanisms responsible for controlling the growth of eye length.

Various examples of the claimed invention are summarized as follows:

According to a first aspect of the present invention, there is provided a pair of eyeglasses, comprising: eyeglass frames; and a pair of ophthalmic lenses mounted in the frames. The lenses comprising a dot pattern distributed across each lens, the dot pattern comprising an array of dots spaced apart by a distance of 1 mm or less, each dot having a maximum dimension in a range from 0.08 mm to 0.5 mm, the dot pattern surrounding a clear aperture free of dots having a dimension of more than 1 mm, and the dots scatter incident light to reduce a contrast of an image formed through the dot pattern compared to the clear aperture.

Implementations of the eyeglasses may include one or more of the following features and/or features of other examples. For example, each dot can have a maximum dimension of 0.2 mm or less (e.g., 0.1 mm or less, 0.05 mm or less, 0.02 mm or less, 0.01 mm or less). In some embodiments, each dot is substantially the same size. The dots may be spaced apart by 0.8 mm or less (e.g., 0.6 mm or less, 0.5 mm or less, 0.4 mm or less, 0.35 mm or less). The dots may be arranged on a square grid, a hexagonal gird, another grid, or in a semi-random or random pattern. The dots may be spaced at regular intervals, e.g., such as 0.55 mm, 0.365 mm, or 0.24 mm. Alternatively, dot spacing may vary depending on the distance of the dot from the center of the lens. For example, dot spacing may increase monotonically or decrease monotonically as the distance from the center of the lens increases.

The dot pattern can include a clear aperture free of dots having a maximum dimension of more than 1 mm, the clear aperture being aligned with a viewing axis of a wearer of the pair of eyeglasses. The clear aperture can have a maximum dimension (e.g., a diameter) of 2 mm or more (e.g., 3 mm or more, 4 mm or more, 5 mm or more, 6 mm or more, 7 mm or more, 8 mm or more) and up to 1.5 cm (e.g., 1.5 cm or less, 1.4 cm or less, 1.3 cm or less, 1.2 cm or less, 1.1 cm or less, 1.0 cm or less). The clear aperture can be substantially circular or a similar shape, such as octagonal, square, or other polygon shape.

In some embodiments, the dots are protrusions on a surface of the corresponding lens. The protrusions can be formed from a transparent material. In some cases, the transparent material is clear and/or colorless. Alternatively, or additionally, at least some of the transparent material can be tinted (e.g., with a dye that absorbs red wavelengths). The transparent material can have substantially the same refractive index as a lens material. The protrusions can be substantially spherical or semi-spherical.

In certain embodiments, the dots are recesses on a surface of the corresponding lens.

The dots can be inclusions between opposing surfaces of each lens.

The lenses can be clear lenses. In some embodiments, the lenses are tinted lenses.

The dot pattern can reduce an image contrast of an object viewed through the dot pattern by at least 30% (e.g., by at least 35%, by at least 40%, by at least 45%, by at least 50%, by at least 55%, by at least 60%) compared to an image contrast of the object viewed through the clear aperture. In some embodiments, the lenses have optical power to correct a wearer's on-axis vision to 20/20 or better (e.g., 20/15) through the clear aperture, and, for at least a portion of the wearer's peripheral vision through the dot pattern, the lenses correct the wearer's vision to 20/25 or better, 20/30 or better, 20/40 or better, and the like.

According to a second aspect of the present invention, there is provided a method of making the eyeglasses as defined in the first aspect, comprising: depositing discrete portions of a material on a surface of the lens corresponding to the dot pattern; and curing the deposited material to provide protrusions on the lens surface forming the dot pattern. The material can be deposited using an inkjet printer. The deposited material can be cured using radiation (e.g., ultraviolet radiation).

According to a third aspect of the present invention, there is provided an ophthalmic lens, comprising: two opposing curved surfaces collectively having an optical power to correct a wearer's on-axis vision to 20/20 or better; and a dot pattern distributed across each lens, the dot pattern comprising an array of spaced apart dots arranged so that, for at least a portion of the wearer's peripheral vision, the lenses correct the wearer's vision to 20/25 or better and reduce an image contrast compared to on-axis image contrast, the dot pattern surrounding a clear aperture free of dots, each dot comprising a depression in a surface of the lens and having a maximum dimension in a range from 0.08 mm to 0.5 mm. Embodiments of the ophthalmic lens may include one or more of the features of other examples.

In general, in a further example, the claimed invention features a pair of eyeglasses customized for a wearer, including: eyeglass frames; and a pair of ophthalmic lenses mounted in the frames, the lenses having optical power to correct the wearer's on-axis vision to 20/20 or better. The eyeglasses include an optical diffuser distributed across each lens, the optical diffuser being configured so that, for at least a portion of the wearer's peripheral vision, the lenses correct the wearer's vision to 20/40 or better, 20/30 or better, or 20/25 or better and reduce an image contrast by at least 30% compared to on-axis image contrast.

Embodiments of the ophthalmic lens may include one or more of the following features and/or features of other examples. For example, the optical diffuser can include a film laminated on a surface of each lens. The lenses may each include a clear aperture free of the optical diffuser having a maximum dimension of more than 1 mm, the clear aperture being aligned with a viewing axis of a wearer of the pair of eyeglasses.

In general, in a further example, the claimed invention features an ophthalmic lens, including: two opposing curved surfaces collectively having an optical power to correct a wearer's on-

axis vision to 20/20 or better; and a dot pattern distributed across each lens, the dot pattern comprising an array of spaced apart dots arranged so that, for at least a portion of the wearer's peripheral vision, the lenses correct the wearer's vision to 20/25 or better and reduce an image contrast by at least 30% compared to on-axis image contrast, the dot pattern including a clear aperture free of dots aligned with a viewing axis of the wearer.

Embodiments of the ophthalmic lens may include one or more of the following features and/or features of other examples. For example, the ophthalmic lens can be an eyeglass lens. Alternatively, in some embodiments, the ophthalmic lens is a contact lens.

In general, in another example, the claimed invention features a method of monitoring and arresting myopia progression in a person, including: measuring variations in a thickness of the person's choroid over a period of time; and providing the person with ophthalmic lenses which reduce an image contrast in the person's peripheral vision compared to an on-axis image contrast.

Implementations of the method can include one or more of the following features and/or features of other example. For example, the ophthalmic lenses may be provided in eyeglasses of the foregoing examples. Alternatively, the ophthalmic lenses may be provided as contact lenses. In some implementations, measuring the variations includes measuring a thickness of the person's choroid using Optical Coherence Tomography (OCT).

Among other advantages, disclosed embodiments feature eyeglasses that include features that reduce signals in the retina responsible for growth of eye length on the lenses for both eyes, without diminishing the user's on-axis vision in either eye to an extent that is disruptive to the user. For example, providing a dot pattern that modestly blurs the wearer's peripheral vision while allowing normal on-axis viewing through a clear aperture allows for all-day, every-day use by the wearer. Disclosed embodiments can also provide therapeutic benefits to a user in both eyes using only a single pair of eyeglasses, in contrast to approaches which involve alternating use of different pairs of eyeglasses.

Moreover, the dot patterns can be largely unnoticeable to others, particularly where dot patterns are clear and colorless and/or where contact lenses are used. The subtlety of the dot patterns can result in more consistent use by certain wearers, especially children, who may otherwise be self-conscious during everyday (e.g., at school or otherwise among peers) use of more conspicuous devices.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1A shows a pair of eyeglasses containing ophthalmic lenses for treating myopia.

WHAT IS CLAIMED IS:

1. A pair of eyeglasses, comprising:

eyeglass frames; and

a pair of ophthalmic lenses mounted in the frames, the lenses comprising a dot pattern distributed across each lens, the dot pattern comprising an array of dots spaced apart by a distance of 1 mm or less, each dot having a maximum dimension in a range from 0.08 mm to 0.5 mm, the dot pattern surrounding a clear aperture free of dots having a dimension of more than 1 mm, and the dots scatter incident light to reduce a contrast of an image formed through the dot pattern compared to the clear aperture.

2. The eyeglasses of claim 1, wherein each dot has a maximum dimension of 0.2 mm or less.

3. The eyeglasses of claim 1, wherein each dot has a maximum dimension of 0.1 mm or less.

4. The eyeglasses of claim 1, wherein each dot is substantially the same size.

5. The eyeglasses of claim 1, wherein the dots are spaced apart by 0.8 mm or less.

6. The eyeglasses of claim 1, wherein the dots are spaced apart by 0.6 mm or less.

7. The eyeglasses of claim 1, wherein the dots are spaced apart by 0.5 mm or less.

8. The eyeglasses of claim 1, wherein the dots are spaced apart by 0.4 mm or less.

9. The eyeglasses of claim 1, wherein the dots are spaced apart by 0.35 mm or less.

10. The eyeglasses of claim 1, wherein the dots are arranged on a square grid.

11. The eyeglasses of claim 1, wherein the clear aperture has a maximum dimension of 2 mm or more.

12. The eyeglasses of claim 1, wherein the clear aperture has a maximum dimension of 3 mm or more.

13. The eyeglasses of claim 1, wherein the clear aperture has a maximum dimension of 4 mm or more.

14. The eyeglasses of claim 1, wherein the clear aperture has a maximum dimension of 5 mm or more.

15. The eyeglasses of claim 1, wherein the clear aperture has a maximum dimension of 6 mm or more.

16. The eyeglasses of claim 1, wherein the clear aperture has a maximum dimension of 7 mm or more.

17. The eyeglasses of claim 1, wherein the clear aperture has a maximum dimension of 8 mm or more.

18. The eyeglasses of claim 1, wherein the clear aperture is substantially circular.

19. The eyeglasses of claim 1, wherein the dots are protrusions on a surface of the corresponding lens.

20. The eyeglasses of claim 19, wherein the protrusions are formed from a transparent material.

21. The eyeglasses of claim 20, wherein the transparent material is clear.

22. The eyeglasses of claim 20, wherein the transparent material is tinted.

23. The eyeglasses of claim 20, wherein the transparent material has substantially the same refractive index as a lens material.

24. The eyeglasses of claim 19, wherein the protrusions are substantially spherical.

25. The eyeglasses of claim 1, wherein the dots are recesses on a surface of the corresponding lens.

26. The eyeglasses of claim 1, wherein the dots are inclusions between opposing surfaces of each lens.

27. The eyeglasses of claim 1, wherein the lenses are clear lenses.

28. The eyeglasses of claim 1, wherein the eyeglasses are tinted eyeglasses.

29. The eyeglasses of claim 1, wherein the dot pattern reduces an image contrast of an object viewed through the dot pattern by at least 30% compared to an image contrast of the object viewed through the clear aperture.

30. The eyeglasses of claim 1, wherein the dot pattern reduces an image contrast of an object viewed through the dot pattern by at least 35% compared to an image contrast of the object viewed through the clear aperture.

31. The eyeglasses of claim 1, wherein the dot pattern reduces an image contrast of an object viewed through the dot pattern by at least 40% compared to an image contrast of the object viewed through the clear aperture.

32. The eyeglasses of claim 1, wherein the dot pattern reduces an image contrast of an object viewed through the dot pattern by at least 45% compared to an image contrast of the object viewed through the clear aperture.

33. The eyeglasses of claim 1, wherein the dot pattern reduces an image contrast of an object viewed through the dot pattern by at least 50% compared to an image contrast of the object viewed through the clear aperture.

34. The eyeglasses of claim 1, wherein the dot pattern reduces an image contrast of an object viewed through the dot pattern by at least 55% compared to an image contrast of the object viewed through the clear aperture.

35. The eyeglasses of claim 1, wherein the dot pattern reduces an image contrast of an object viewed through the dot pattern by at least 60% compared to an image contrast of the object viewed through the clear aperture.

36. The eyeglasses of claim 1, wherein the lenses having optical power to correct a wearer's on-axis vision to 20/20 or better through the clear aperture, and, for at least a portion of the wearer's peripheral vision through the dot pattern, the lenses correct the wearer's vision to 20/25 or better.

37. A method of making the eyeglasses of claim 1, comprising:

depositing discrete portions of a material on a surface of the lens corresponding to the dot pattern; and

curing the deposited material to provide protrusions on the lens surface forming the dot pattern.

38. The method of claim 37, wherein the material is deposited using an inkjet printer.

39. The method of claim 37, wherein the deposited material is cured using radiation.

40. The method of claim 39, wherein the radiation comprises ultraviolet radiation.

41. An ophthalmic lens, comprising:

two opposing curved surfaces collectively having an optical power to correct a wearer's on-axis vision to 20/20 or better; and

a dot pattern distributed across each lens, the dot pattern comprising an array of spaced apart dots arranged so that, for at least a portion of the wearer's peripheral vision, the lenses correct the wearer's vision to 20/25 or better and reduce an image contrast compared to on-axis image contrast, the dot pattern surrounding a clear aperture free of dots, each dot comprising a depression in a surface of the lens and having a maximum dimension in a range from 0.08 mm to 0.5 mm.

42. The ophthalmic lens of claim 41, wherein the ophthalmic lens is an eyeglass lens.

43. The ophthalmic lens of claim 41, wherein the ophthalmic lens is a contact lens.