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(54) **DISPOSABLE OPHTHALMIC LENS**

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(57) **ABSTRACT**

An ophthalmic lens with high definition, wide field of view and high magnification has, in one embodiment, a contact lens, an intermediate field lens and an image lens wherein a real image is formed inside the field lens. At least two of the lenses contribute to the magnification and three surfaces of the ophthalmic lens are aspheric to provide a better defined image. The ophthalmic lens is made disposable with high quality plastic lenses and a plastic holder. A portion of the holder changes appearance in response to change in environment to indicate that the disposable lens has been used.

**47 Claims, 1 Drawing Sheet**

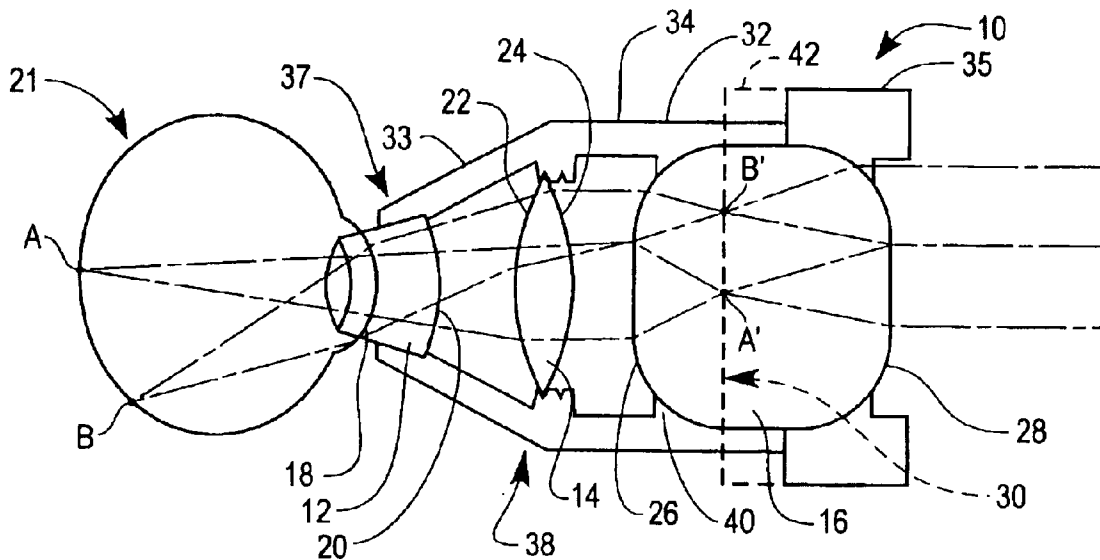


Fig. 1

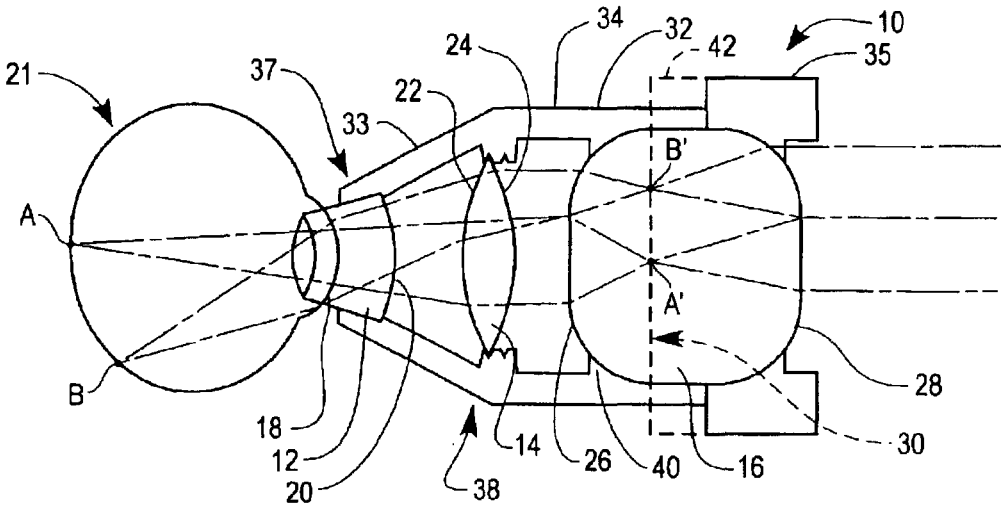


Fig. 2

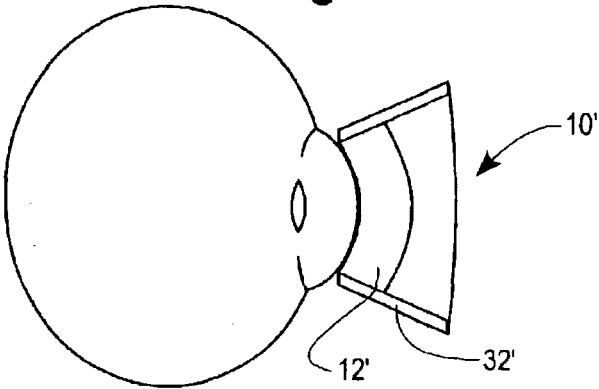
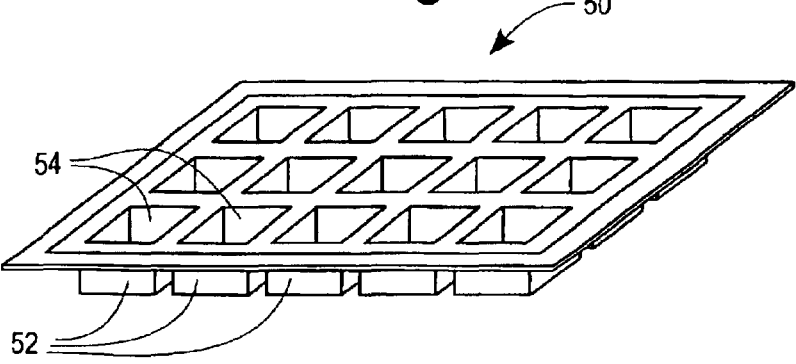


Fig. 3



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**DISPOSABLE OPHTHALMIC LENS****CROSS-REFERENCE TO RELATED APPLICATIONS**

N/A

**STATEMENT REGARDING FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT**

N/A

**TECHNICAL FIELD**

The present invention relates to an ophthalmic lens for diagnostic and/or surgical uses. The ophthalmic lens provides a wide field of view, high magnification and a well-defined image. The ophthalmic lens is also made to be disposable.

**BACKGROUND OF THE INVENTION**

Typical ophthalmic lens are such that they have either high magnification and a relatively limited field of view or they have a wide field of view and a low magnification. Depending upon the particular use of the ophthalmic lens, one or the other of these types of ophthalmic lenses is chosen. One known ophthalmic lens as shown in U.S. Pat. No. 4,728,813 includes a contact lens formed of polymethylmethacrylate and an aspheric lens formed of glass. The aspheric lens and contact lens are supported in a housing with a fixed spacing between the lenses. This ophthalmic lens forms a real image of the patient's fundus in air. Another known ophthalmic lens includes three elements, a contact lens and two elements cemented together to form an image lens wherein the lenses are all formed of glass. This ophthalmic lens is such that a real image of the fundus is formed inside the image lens. Moreover, the image lens provides all of the optical power in this ophthalmic lens for magnification of the fundus. As such, the image lens is very thick, being on the order of 1.25 inches. This ophthalmic lens provides a relatively wide field of view but low magnification. Heretofore, a wide field of view and high magnification were thought to be mutually exclusive attributes of an ophthalmic lens.

Because a number of diseases, such as AIDS, can be transmitted by contact with the eye, it is critically important that the ophthalmic lens be sterilized before each use. As such, in all of the known ophthalmic lenses, including those described above, the housing or holder for the lenses is made of a metal capable of withstanding the high temperatures of autoclaving without degradation. Because of the housing material and the use of glass aspheric lenses, known ophthalmic lenses are extremely costly.

**BRIEF SUMMARY OF THE INVENTION**

In accordance with the present invention, the disadvantages of prior ophthalmic lenses have been overcome. The ophthalmic lens of the present invention provides both high magnification and a wide field of view. In accordance with a further feature of the present invention, the ophthalmic lens is made to be disposable.

More particularly, in accordance with one feature of the present invention, a disposable ophthalmic lens includes a plastic holder supporting one or more lenses. A sterile contact lens formed of a transparent plastic is mounted in the holder, the contact lens having a first surface shaped to

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contact an eye when in use. The holder, with one or more lenses including the contact lens mounted therein, is enclosed in a package that maintains the contact lens free from contamination before use.

5 In accordance with one embodiment of the present invention, at least a portion of the holder is formed of a material that changes appearance in response to a change in the holder's environment. In a preferred embodiment, the holder portion is formed of a photoreactive material that changes color in the presence of light. In this embodiment, the package is made of a non-light transmissive material so as to prevent the holder portion from changing color while enclosed in the package. After the package is opened and the holder taken out for use, the exposure to light will change the color of the holder portion to indicate that the ophthalmic lens has been used and should be disposed of. Thus, the present invention prevents inadvertent use of an ophthalmic lens that has already been used and is not sterile.

10 In accordance with a further feature of the present invention, the contact lens is mounted in a first end of the holder, the contact lens having a surface opposite the surface shaped to contact the eye that is aspheric. An intermediate lens is mounted in the holder and spaced between the contact lens and an image lens wherein the intermediate lens bends peripheral rays from the contact lens towards the image lens and contributes optical power to the ophthalmic lens. An image lens is mounted in a second end of the holder with a positive first surface through which rays from the intermediate lens enter and are focused to form a real image inside of the image lens. A second surface of the image lens further magnifies the real image. This ophthalmic lens provides a very wide field of view that is, for example, greater than or equal to 60° and has high magnification. In a preferred embodiment, both the first and second surfaces of the image lens are aspheric surfaces as well as the anterior surface of the contact lens. The three aspheric surfaces contribute to an extremely high quality, well-defined image in addition to the wide field of view and high magnification.

20 These and other advantages and novel features of the present invention, as well as details of an illustrated embodiment thereof, will be more fully understood from the following description and drawings.

**BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWING**

25 **FIG. 1** is a cross-sectional view of an ophthalmic lens in accordance with one embodiment of the present invention having a contact lens, intermediate lens and image lens mounted in a holder for diagnostic and/or surgical use;

30 **FIG. 2** is a cross-sectional view of an ophthalmic lens in accordance with a second embodiment of the present invention for diagnostic use; and

35 **FIG. 3** is a perspective view of one embodiment of a package for a plurality of disposable lenses.

**DETAILED DESCRIPTION OF THE INVENTION**

40 The ophthalmic lens **10** of the present invention as shown in **FIG. 1** provides a better defined image than known ophthalmic lenses while providing a very wide field of view and high magnification. These advantages are attained by the use of three spaced lenses including a contact lens **12**, an intermediate field lens **14** and an image lens **16** wherein a real image of the interior of an eye is formed inside the image lens **16**.

More particularly, the contact lens **12** has a surface **18** having an approximate shape of a cornea and is intended to contact the eye in use. For example, the surface **18** may be spherical having a radius of curvature of approximately 7.8 mm, although other radii can be used as will be apparent to one of ordinary skill. The opposite surface **20** of the contact lens **12** is shaped so as to neutralize the optical power of the patient's cornea so that the rays exiting the contact lens from a point on the retina **21** of a patient's eye are approximately parallel.

The rays exiting from the contact lens **12** enter a surface **22** of the field lens **14**. The field lens **14** bends the peripheral image rays such as from point B towards the image lens **16**. The field lens **14** also contributes to the optical power of the ophthalmic lens **10**. Each of the surfaces **22** and **24** of the field lens **14** is a spherical surface. However, one or both of these surfaces can be made aspheric if desired.

Rays enter a positive surface **26** of the image lens **16** and are focused by the positive curvature of the surface **26** to form a real, inverted image of the patient's retina **21** inside of the image lens **16**. The opposite or anterior surface **28** of the image lens **16** has a curvature to magnify the real image **30**. Further, each of the surfaces **26** and **28** is an aspheric surface.

In a preferred embodiment of the present invention, each of the aspheric surfaces **20**, **26** and **28** of the ophthalmic lens is formed of an aspheric surface defined by the following equation.

$$Z = \frac{Cr^2}{1 + \sqrt{1 - (1+k)C^2r^2}} + A_1r^2 + A_2r^4 + A_3r^6 \dots$$

For surface **20**, the following values are preferred.

$$\begin{aligned} 1/C &= 6.82 \pm 1 \\ K &= -0.27 \\ A_1 &= -0.00023 \pm 0.1 \\ A_2 &= 0.000074 \pm 0.1 \\ A_3 &= 0 \pm 0.001 \end{aligned}$$

For surface **22**, the following values are preferred.

$$\begin{aligned} 1/C &= 24 \pm 3 \\ K &= -1.65 \pm 0.2 \\ A_1 &= 0.02 \pm 0.01 \\ A_2 &= 4 \times 10^{-6} \pm 5 \times 10^{-6} \\ A_3 &= 1.3 \times 10^{-8} \pm 1 \times 10^{-8} \end{aligned}$$

For surface **24**, the following values are preferred.

$$\begin{aligned} 1/C &= -32 \pm 3 \\ K &= -2.7 \pm 0.5 \\ A_1 &= 0.003 \pm 0.002 \\ A_2 &= 4.0 \times 10^{-6} \pm 1.0 \times 10^{-6} \\ A_3 &= 9.5 \times 10^{-9} \pm 1.5 \times 10^{-9} \end{aligned}$$

For surface **26**, the following values are preferred.

$$\begin{aligned} 1/C &= 21.8 \pm 3 \\ K &= 1.7 \pm 1 \\ A_1 &= -0.02 \pm 0.01 \\ A_2 &= 6 \times 10^{-5} \pm 2 \times 10^{-4} \\ A_3 &= -4.7 \times 10^{-8} \pm 4.0 \times 10^{-9} \end{aligned}$$

For surface **28**, the following values are preferred.

$$\begin{aligned} 1/C &= -25 \\ K &= -3.0 \pm 1 \\ A_1 &= 0 \pm 0.05 \\ A_2 &= 0 \pm 0.05 \\ A_3 &= 0 \pm 0.05 \end{aligned}$$

In accordance with a further feature of the present invention, the ophthalmic lens **10** is made disposable by forming each of the three lenses **12**, **14**, and **16** of a transparent optical plastic such as polymethylmethacrylate or PMMA. Heretofore, it was thought that lenses having aspheric surfaces should be formed of glass. However, it has been found, that in accordance with the present invention, an aspheric surface such as described above can be formed of an ophthalmic plastic such as PMMA by injection molding, compression molding, casting and further by CNC machining. Moreover, the lenses **12**, **14** and **16** are supported in a housing or holder **32** that is also formed of plastic. In particular, the holder **32** is preferably formed of an acrylic, styrene or polycarbonate.

In a preferred embodiment of the present invention, at least a portion of the holder **32** is formed of a material that changes appearance in response to environmental changes. For example, the holder portion can include a dye that changes color in the absence or presence of water. In this embodiment, the ophthalmic lens **10** would be packaged in a sterile saline solution for example. When the lens is taken out of the package, the color of that portion of the holder **32** containing the dye would change color as the ophthalmic lens **10** dries. In a preferred embodiment of the present invention, a portion of the holder **32** includes a dye that changes color as the material absorbs light. A suitable photoreactive or photochromic dye in accordance with this embodiment of the present invention is available from Color Change Corporation of Addison, Ill. In a preferred embodiment, the color change is also irreversible. The package enclosing an ophthalmic lens **10** with a photoreactive holder portion is preferably formed of a material that is non-light transmissive so that it blocks light to prevent the lens from changing colors prior to use. When the ophthalmic lens packaging is opened and the ophthalmic lens **10** exposed to light, the holder **32** changes color to indicate that it has been used. The holder **32** may change color, for example, from blue to yellow or green to red such that there is a significant color change to indicate that the ophthalmic lens **10** has already been used and should not be re-used but should be disposed of.

A disposable ophthalmic lens in accordance with the present invention need not have three lenses as illustrated in FIG. 1. In an alternative embodiment as shown in FIG. 2, an ophthalmic lens **10'** having a single lens in the form of a fundus contact lens **12'** is supported in a cone or holder **32'**. In this embodiment, the entire holder **32'** is preferably formed of a material containing the photochromic or photoreactive dye. The holder **32**, such as shown in FIG. 1, may be formed of multiple sections. For example, a section **33** has an end **37** for supporting the contact lens **12** and an end **38** with a flange for supporting the field lens **14**. An intermediate section **34** with another flange may screw onto the section **33** to hold the field lens **14** in place. The section **34** also includes a flange **40** or the like for supporting the image lens **16**. A section **35** of the holder **32** preferably screws onto the section **34** of the holder **32** so as to retain the image lens **16** in place. In this embodiment, one or more of the surfaces **33**, **34** and **35** can be formed of a material containing the dye that changes appearance in response to environmental changes. In a further embodiment, a member **42** containing the dye that changes appearance in response to environmental changes can be mounted on an outer surface of the holder **32** so as to form a portion of the holder although it is not integral therewith. Other variations of the holder of the present invention can be made as well.

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FIG. 3 illustrates one embodiment of a package for a plurality of ophthalmic lenses 10 in accordance with the present invention. In this embodiment, the package is formed of a tray 50 having a number of individual compartments 52 for holding a respective, disposable ophthalmic lens 10. Each compartment 52 has a foil cover 54 or the like that can be individually removed without removing the cover of an adjacent compartment 52 so that one ophthalmic lens 10 can be removed from the tray 50 without altering the environment of the ophthalmic lenses contained in the adjacent compartments 52. In an alternative embodiment, each ophthalmic lens 10 can be contained in its own individual wrapper that controls the environment of the ophthalmic lens 10 prior to use. It should be appreciated that, the ophthalmic lens 10 is sterilized and thereafter packaged wherein the packaging is such that it maintains the ophthalmic lens 10 free from contaminants prior to use.

Many modifications and variations of the present invention are possible in light of the above teachings. Thus, it is to be understood that, within the scope of the appended claims, the invention may be practiced otherwise than as described hereinabove.

What is claimed and desired to be secured by Letters Patent is:

1. A disposable ophthalmic lens used in contact with an eye comprising:

- a holder supporting one or more lenses, at least a portion of the holder being formed of a material that is photo-reactive so as to change color in the presence of light;
- a contact lens formed of a transparent material other than glass mounted in the holder, the lens having a first surface shaped to contact an eye when in use;
- a non-light transmissive package enclosing the holder and contact lens to prevent the holder portion from changing color while enclosed in the package.

2. A disposable ophthalmic lens as recited in claim 1 wherein said contact lens is formed of polymethylmethacrylate.

3. A disposable ophthalmic lens as recited in claim 1 wherein the holder is formed of a plastic with a photochromic dye in the portion thereof that changes color.

4. A disposable ophthalmic lens as recited in claim 1 wherein the holder is formed of acrylic with a photochromic dye in the portion thereof that changes color.

5. A disposable ophthalmic lens as recited in claim 1 wherein the holder is formed of styrene with a photochromic dye in the portion thereof that changes color.

6. A disposable ophthalmic lens as recited in claim 1 wherein the holder is formed of polycarbonate with a photochromic dye in the portion thereof that changes color.

7. A disposable ophthalmic lens as recited in claim 1 wherein the color change of the holder portion is irreversible.

8. A disposable ophthalmic lens as recited in claim 1 wherein said contact lens is formed of a plastic.

9. A disposable ophthalmic lens as recited in claim 1 wherein the contact surface of the contact lens has an approximate shape of a cornea and a surface of the contact lens opposite the contact surface is aspheric.

10. A disposable ophthalmic lens as recited in claim 1 wherein the contact lens is mounted in a first end of the holder, a second lens is mounted in an end of the holder opposite the first lens and a third lens is disposed between the first and second lenses.

11. A disposable ophthalmic lens as recited in claim 10 wherein the second and third lenses are formed of a material other than glass.

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12. A disposable ophthalmic lens as recited in claim 11 wherein the contact lens, second lens and third lens are formed of polymethylmethacrylate.

13. A disposable ophthalmic lens as recited in claim 10 wherein a real image is formed in the second lens.

14. A disposable ophthalmic lens as recited in claim 10 wherein the contact lens has an aspheric surface opposite the contact surface and the second lens has a first and second surface both of which are aspheric.

15. A disposable ophthalmic lens as recited in claim 10 wherein each of the second and third lenses contributes to the optical power of the ophthalmic lens.

16. A disposable ophthalmic lens as recited in claim 10 wherein the ophthalmic lens has a field of view that is greater than or equal to 60°.

17. A disposable ophthalmic lens used in contact with an eye comprising:

- a contact lens formed of a transparent plastic, the lens having a surface shaped to contact an eye when in use;
- a holder for supporting one or more lenses when the ophthalmic lens is in use including the contact lens, the holder having an aperture therein for receiving the one or more lenses and at least a portion of the holder being formed of a material that changes appearance in response to a change in the holder's environment to indicate that the ophthalmic lens should be disposed of.

18. A disposable ophthalmic lens as recited in claim 17 wherein the change in appearance is irreversible.

19. A disposable ophthalmic lens as recited in claim 18 wherein the contact lens is formed of polymethylmethacrylate.

20. A disposable ophthalmic lens as recited in claim 18 wherein the contact lens is an injection molded lens.

21. A disposable ophthalmic lens as recited in claim 18 wherein the contact lens is a compression molded lens.

22. A disposable ophthalmic lens as recited in claim 18 wherein the contact lens is a cast lens.

23. A disposable ophthalmic lens as recited in claim 18 wherein the contact lens is a machined lens.

24. A disposable ophthalmic lens as recited in claim 17 wherein the material of the holder is photoreactive so as to change colors when exposed to light.

25. A disposable ophthalmic lens as recited in claim 24 including a non-light transmissive package enclosing the holder and contact lens.

26. A disposable ophthalmic lens as recited in claim 24 wherein the color change on exposure to light is irreversible.

27. A disposable ophthalmic lens as recited in claim 17 including at least one other lens supported in the holder, all of the lens being formed of a transparent plastic.

28. A disposable ophthalmic lens as recited in claim 17 including an image lens mounted in an end of the holder opposite an end of the holder in which the contact lens is mounted and a field lens disposed between the contact lens and image lens.

29. A disposable ophthalmic lens as recited in claim 28 wherein said ophthalmic lens has at least three aspheric surfaces.

30. A disposable ophthalmic lens as recited in claim 29 wherein one of the aspheric surfaces is a surface of the contact lens and the two other aspheric surfaces are surfaces of the image lens.

31. A disposable ophthalmic lens as recited in claim 17 wherein the contact lens has a surface opposite the eye contacting surface that is aspheric.

32. A disposable ophthalmic lens used in contact with an eye comprising:

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- a plurality of lenses formed of a transparent material other than glass, including a contact lens having a surface shaped to contact an eye when in use and having an opposite surface that is aspheric;
- a holder for supporting the plurality of lenses, at least a portion of the holder being formed of a material that changes color to indicate the ophthalmic lens has been used.
- 33. A disposable ophthalmic lens as recited in claim 32 wherein the color change is irreversible.
- 34. A disposable ophthalmic lens as recited in claim 32 wherein the lenses are formed of a transparent plastic.
- 35. A disposable ophthalmic lens as recited in claim 34 wherein the lenses are formed of polymethylmethacrylate.
- 36. A disposable ophthalmic lens as recited in claim 34 wherein the lenses are compression molded lenses.
- 37. A disposable ophthalmic lens as recited in claim 34 wherein the lenses are cast lenses.
- 38. A disposable ophthalmic lens as recited in claim 34 wherein the lenses are machined.
- 39. A disposable ophthalmic lens as recited in claim 32 wherein the material that changes color is photoreactive so as to change colors when exposed to light.
- 40. A disposable ophthalmic lens as recited in claim 39 including a non-light transmissive package enclosing the holder and contact lens prior to use.
- 41. A disposable ophthalmic lens as recited in claim 32 including an image lens mounted in an end of the holder opposite an end of the holder in which the contact lens is mounted and a field lens disposed between the contact lens and image lens.
- 42. A disposable ophthalmic lens as recited in claim 41 wherein said ophthalmic lens has at least three aspheric surfaces.
- 43. A disposable ophthalmic lens as recited in claim 42 wherein one of the aspheric surfaces is a surface of the contact lens and the two other aspheric surfaces are surfaces of the image lens.
- 44. A disposable ophthalmic lens as recited in claim 32 wherein the contact lens has a field of view greater than or equal to 60°.
- 45. A disposable ophthalmic lens used in contact with an eye comprising:
  - a plastic holder supporting one or more lenses when the ophthalmic lens is in use;
  - a sterile contact lens formed of a transparent plastic mounted in the holder, the contact lens having a first surface shaped to contact an eye when in use and a second surface that is aspheric; and
  - a package enclosing the holder supporting one or more lenses including the contact lens to maintain the contact lens free from contamination, the holder and contact

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- lens being disposable after use wherein at least a portion of the holder is photoreactive so as to change color when exposed to light and the package is non-light transmissive.
- 46. An ophthalmic lens used in contact with an eye comprising:
  - a holder supporting a plurality of lenses;
  - a contact lens mounted in a first end of the holder, the contact lens having a first surface shaped to contact an eye when in use and a second surface that is aspheric, wherein the aspheric surface is defined by the equation

$$Z = \frac{Cr^2}{1 + \sqrt{1 - (1+k)C^2r^2}} + A_1r^2 + A_2r^4 + A_3r^6$$

- where C, k, A<sub>1</sub>, A<sub>2</sub> and A<sub>3</sub> are constants and r is a radius;
- an image lens mounted in a second end of the holder with a positive first surface through which rays enter and are focused to form a real image inside the lens and a second surface that magnifies the real image; and
- an intermediate lens mounted in the holder and spaced between the contact lens and the image lens, the intermediate lens contributing optical power and wherein the ophthalmic lens has a field of view greater than or equal to 60°.

- 47. An ophthalmic lens used in contact with an eye comprising:
  - a holder supporting a plurality of lenses;
  - a contact lens mounted in a first end of the holder, the contact lens having a first surface shaped to contact an eye when in use and a second surface that is aspheric;
  - an image lens mounted in a second end of the holder with a positive first surface through which rays enter and are focused to form a real image inside the lens and a second surface that magnifies the real image, the first and second surfaces of the image lens being aspheric; and
  - an intermediate lens mounted in the holder and spaced between the contact lens and image lens to contribute optical power to the ophthalmic lens and wherein the aspheric surfaces of the contact lens and image lens are defined by

$$Z = \frac{Cr^2}{1 + \sqrt{1 - (1+k)C^2r^2}} + A_1r^2 + A_2r^4 + A_3r^6$$

- where C, k, A<sub>1</sub>, A<sub>2</sub> and A<sub>3</sub> are constants and r is a radius.

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