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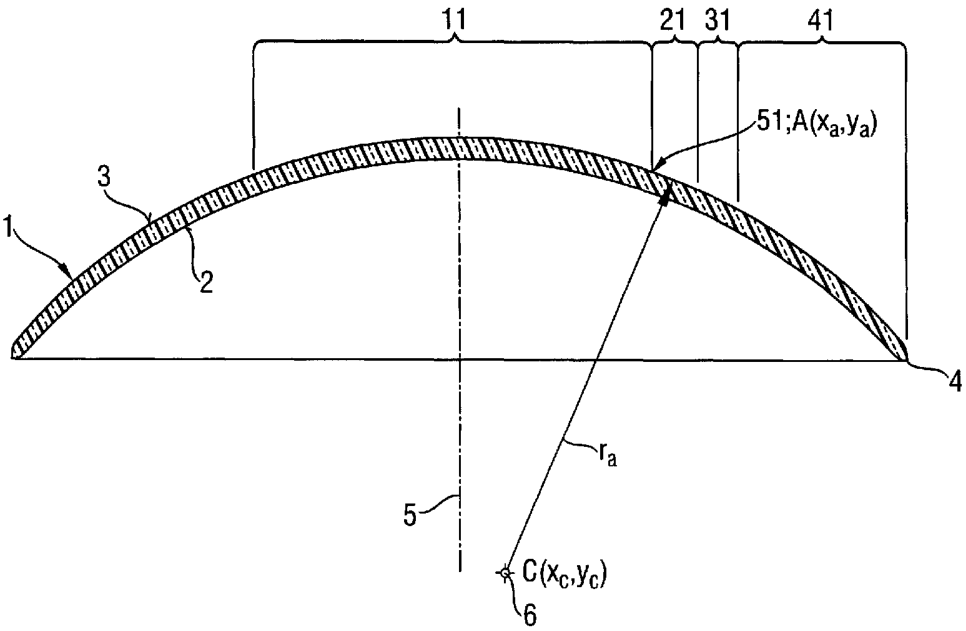
(54) **Title:** CONTACT LENSES WITH OFF-CENTER SPHERE SURFACE



(57) **Abstract:** The present invention provides a contact lens comprising a convex surface and a concave surface, one or both of the surfaces comprising: a) a central optical zone that is an aspherical sub-surface; b) a transition zone that is adjacent to said central optical zone, wherein and is a rotationally symmetric off-center sphere sub-surface; and c) a peripheral zone that comprises one or more sphere sub-surfaces, wherein all sub-surfaces are tangent to each other. By having a transition zone of the present invention, flexion points at the junction of optical zone with peripheral zone can be eliminated. The present invention also provides a method for producing a contact lens of the present invention.

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Contact Lenses with Off-Center Sphere Surface

This invention is related to contact lenses. In particular, the present invention is related to contact lenses each of which has a convex (front) surface and a concave (back) surface, on one or both of the surfaces the first derivative is continuous from the center to the edge.

BACKGROUND

It is well known that contact lenses can be used for cosmetics and the correction of visual acuity. The ideal contact lens is one which is not only comfortable to wear for extended periods of time, but also easily manufactured at minimum cost in time and labor.

Generally, the front, or convex, surface of a contact lens comprises an optic zone, one or more peripheral zones that are adjacent to the optical zone, and an edge, wherein the peripheral zones are typical sphere surfaces. The presence of all but the optic zone is necessitated by the need for the contact lens to fit comfortably, for the lens to position itself correctly on the wearer's eye, and for the lens to be easily handled by the lens wearer.

However, where the optical zone is an aspherical surface, the use of one or more peripheral zones that are adjacent to the optical zone is problematic. For example, the peripheral zone forms a junction with the optical zone, which may comprises flexion points at the junction. Such flexion points may result in differential pressure on the wearer's eye and therefore may have adverse effects on the comfort and ocular health. Therefore, there is a need for a contact lens that overcomes some or all of these disadvantages and can be easily manufactured at minimum cost in time and labor.

SUMMARY OF THE INVENTION

In one embodiment, the present invention provides a contact lens comprising a convex surface and a concave surface, one or both of the surfaces comprising: a) a central optical zone that is an aspherical sub-surface; b) a transition zone that is adjacent to said central optical zone, wherein and is a rotationally symmetric off-center sphere sub-surface; and c) a peripheral zone that comprises one or more sphere sub-surfaces, wherein all sub-surfaces are tangent to each other.

In another embodiment, the present invention provides a series of contact lenses comprising contact lenses having different power corrections, wherein each contact lens in the series has at least one surface comprising: a) a central optical zone that is an aspherical sub-surface; b) a transition zone that is adjacent to said central optical zone, wherein the transition zone is a rotationally symmetric off-center sphere sub-surface; and c) a peripheral zone that comprises one or more sphere sub-surfaces, wherein all sub-surfaces are tangent to each other.

In a further embodiment, the present invention provides a method for producing a contact lens, the method comprising the steps of providing a convex surface and a concave surface, one or both of the surfaces comprising: a) a central optical zone that is an aspherical sub-surface; b) a transition zone that is adjacent to said central optical zone, wherein the transition zone is a rotationally symmetric off-center sphere sub-surface; and c) a peripheral zone that comprises one or more sphere sub-surfaces, wherein all sub-surfaces are tangent to each other.

BRIEF DESCRIPTION OF THE DRAWING

The sole FIGURE illustrates schematically a sectional view of a representative contact lens.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

With reference to the FIGURE, contact lens **1** has a concave (or back) surface **2**, a convex (or front) surface **3** meeting at edge **4**, and an axis **5** passing through the apex of the convex surface **3**. Convex surface **3** comprises central optical zone **11**, transition zone **21**, blend zone **31**, and peripheral zone **41**.

Central optical zone **11** may be an aspherical surface, such as conic, polynomial, or the like. Preferably, central optical zone is an aspherical optical surface that can be described by a function form of:

$$y_{opz} = \frac{x^2}{r\left(1+\sqrt{1-\frac{1+\kappa}{r_0^2}x^2}\right)} \quad \text{or} \quad y_{opz} = a_0 + a_1 x + a_2 x^2 + \ldots + a_n x^n \qquad (1)$$

wherein r_0 is the radius at the apex of the aspherical sub-surface, κ is a conic constant, $a_0 \ldots a_n$ are coefficient constants. The precise geometry is selected to correspond to the lens' wearer's required prescriptive power.

The optical zone of the concave surface **2** of lens **1** may be of any desired geometry, such as a toric, or cylindrical, surface centered about a toric axis that corrects for the wearer's astigmatism. As known in the art, the front central zone and back central zone combine to provide the lens with a given refractive correction.

The transition zone **21** is a rotationally symmetric off-center sphere surface. The radius r_a of the rotationally symmetric off-center sphere surface can be calculated by the formula:

$$r_a = \frac{\left\{1+\left[y'_{opz}(x_a)\right]^2\right\}^{3/2}}{y''_{opz}(x_a)} \qquad (2)$$

wherein $y'_{opz}(x_a)$ is the 1st derivative of the aspherical function form (1) at a junction point **51** $A(x_a,y_a)$ of the transition zone **21** with the central optical zone **11**, $y''_{opz}(x_a)$ is the 2nd derivative of the aspherical function form (1) at the junction point **51** $A(x_a,y_a)$. The center **6** $C(x_c,y_c)$ of the curvature radius r_a can be calculated by formula (3) and (4)

$$x_c = x_a - \frac{y'_{opz}(x_a)\cdot\left\{1+\left[y'_{opz}(x_a)\right]^2\right\}}{y''_{opz}(x_a)} \qquad (3)$$

$$y_c = y_a + \frac{\left\{1+\left[y'_{opz}(x_a)\right]^2\right\}}{y''_{opz}(x_a)} \qquad (4)$$

By using function forms 1-4, the generated transition zone **21** is tangent to the central optical zone at point A **51**.

Peripheral zone **41** can be a sphere surface or multiple spheres surfaces with fillet between two neighboring sphere surfaces.
By adding a transition zone, which is a rotationally symmetric off-center sphere surface, any flexion point at the junction of the central optical zone with the transition zone can be eliminated. Therefore, it can be ensured that all surfaces of the convex surface are tangent to each other, i.e., the first derivative is continuous on the convex surface from the center (apex) to the edge.

Another advantage of adding a transition zone of the invention is the simplicity for implementing it in the lens design and manufacturing. It should be understood that by using a complex mathematical function, such as spline, one can also ensure all sub-surfaces of the convex surface of a contact lens are tangent to each other. However, the incorporation of complex mathematical functions in the lens design is likely to increase the cost of manufacturing.

The transition zone of the invention can also be incorporated in the concave surface of a contact lens or in both the convex and concave surfaces of a contact lens.

Contact lenses useful with the transition zone of the invention may be either hard or soft lenses. Soft contact lenses, made of any material suitable for producing such lenses, preferably are used. The lenses of the invention may have any of a variety of corrective optical characteristics incorporated onto the surfaces. For example, the lens may have any one or more of spheric, aspheric, bifocal, multifocal, prismatic, or cylindric corrections. These corrections may be on either or both the convex or concave surface. For example, the lens of the invention is a toric soft contact lens, meaning that the contact has a cylindrical optical surface, or power, to correct for the wearer's astigmatism.

Contact lenses can now be manufactured that incorporate the transition zone into at least one of the lens surfaces. Contact lenses of the invention may be produced by any convenient means. Preferably, contact lenses are molded from contact lens molds including molding surfaces that replicate the contact lens surfaces when a lens is cast in the molds. For example, an optical cutting tool with a numerically controlled lathe may be used to form a metallic optical tool incorporating the rotationally symmetric off-center sphere surface of the invention. The tool is then used to make convex surface molds that are then used, in conjunction with concave surface molds, to form the lens of the invention using a suitable liquid lens-forming material placed between the molds followed by compression and curing of the lens-forming material. Accordingly, contact lenses according to the invention can be manufactured by providing contact lens molds having a molding surface that comprises: a) a central optical zone that is an aspherical sub-surface; b) a transition zone that is adjacent to said central optical zone, wherein and is a rotationally symmetric off-center sphere sub-surface; and c) a peripheral zone that comprises one or more sphere sub-surfaces, wherein all sub-surfaces are tangent to each other.

It will be understood by those of ordinary skill in the art that various other changes of the details of the invention described may be made. Such changes are intended to be included within the scope of the invention claimed.

What is claimed is:

1. A contact lens comprising a convex surface and a concave surface, one or both of the surfaces comprising:
   a) a central optical zone that is an aspherical sub-surface;
   b) a transition zone that is adjacent to said central optical zone, wherein said transition zone is a rotationally symmetric off-center sphere sub-surface; and
   c) a peripheral zone that comprises one or more sphere sub-surfaces.

   wherein all sub-surfaces are tangent to each other.

2. A contact lens of claim 1, further comprising a blend zone between said transition zone and said peripheral zone.

3. A contact lens of claim 1, wherein said central optical zone is described by an aspherical function form of

$$y_{opz} = \frac{x^2}{r\left(1+\sqrt{1-\frac{1+\kappa}{r_0^2}x^2}\right)} \quad \text{or} \quad y_{opz} = a_0 + a_1 x + a_2 x^2 + \ldots + a_n x^n \qquad (1)$$

wherein r_0 is the radius at the apex of the aspherical sub-surface, κ is a conic constant, a_0, ..., a_n are coefficient constants.

4. A contact lens of claim 3, wherein said rotationally symmetric off-center sphere surface has a curvature radius (r_a) defined by a functional form (2)

$$r_a = \frac{\left\{1+\left[y'_{opz}(x_a)\right]^2\right\}^{3/2}}{y''_{opz}(x_a)} \qquad (2)$$

wherein $y'_{opz}(x_a)$ is the 1st derivative of the aspherical function form (1) at a junction point $A(x_a,y_a)$ of the transition zone with the central optical zone, $y''_{opz}(x_a)$ is the 2nd derivative of the aspherical function form (1) at the junction point $A(x_a,y_a)$, and wherein the center $C(x_c,y_c)$ of the curvature radius r_a is given by formula (3) and (4)

$$x_c = x_a - \frac{y'_{opz}(x_a)\cdot\left\{1+\left[y'_{opz}(x_a)\right]^2\right\}}{y''_{opz}(x_a)} \qquad (3)$$

$$y_c = y_a + \frac{\left\{1 + \left[y'_{opz}(x_a)\right]^2\right\}}{y''_{opz}(x_a)} \qquad (4)$$

5. A contact lens of claim 4, wherein said convex surface comprises said central optical zone, said transition zone, and said peripheral zone.

6. A contact lens of claim 4, wherein said concave surface comprises said central optical zone, said transition zone, and said peripheral zone.

7. A contact lens of claim 1, wherein said contact lens is a soft contact lens.

8. A contact lens of claim 1, wherein said peripheral zone comprises multiple sphere sub-surfaces with fillet between two neighboring sphere sub-surfaces.

9. A method of producing a contact lens, comprising the steps of providing a convex surface and a concave surface, one or both of the surfaces comprising:
   a) a central optical zone that is an aspherical sub-surface;
   b) a transition zone that is adjacent to said central optical zone, wherein said transition zone is a rotationally symmetric off-center sphere sub-surface; and
   c) a peripheral zone that comprises one or more sphere sub-surfaces.

   wherein all sub-surfaces are tangent to each other.

10. A method of claim 9, wherein said central optical zone is described by an aspherical function form of

$$y_{opz} = \frac{x^2}{r\left(1 + \sqrt{1 - \frac{1+\kappa}{r_0^2} x^2}\right)} \quad \text{or} \quad y_{opz} = a_0 + a_1 x + a_2 x^2 + \ldots + a_n x^n \qquad (1)$$

wherein r_0 is the radius at the apex of the aspherical sub-surface, κ is a conic constant, $a_0, \ldots, a_n$ are coefficient constants.

11. A method of claim 10, wherein said rotationally symmetric off-center sphere surface has a curvature radius (r_a) defined by a functional form (2)

$$r_a = \frac{\left\{1+\left[y'_{opz}(x_a)\right]^2\right\}^{3/2}}{y''_{opz}(x_a)} \quad (2)$$

wherein $y'_{opz}(x_a)$ is the 1[st] derivative of the aspherical function form (1) at a junction point $A(x_a,y_a)$ of the transition zone with the central optical zone, $y''_{opz}(x_a)$ is the 2[nd] derivative of the aspherical function form (1) at the junction point $A(x_a,y_a)$, and wherein the center $C(x_c,y_c)$ of the curvature radius r_a is given by formula (3) and (4)

$$x_c = x_a - \frac{y'_{opz}(x_a)\cdot\left\{1+\left[y'_{opz}(x_a)\right]^2\right\}}{y''_{opz}(x_a)} \quad (3)$$

$$y_c = y_a + \frac{\left\{1+\left[y'_{opz}(x_a)\right]^2\right\}}{y''_{opz}(x_a)} \quad (4)$$

12. A method of claim 11, wherein said convex surface comprises said central optical zone, said transition zone, and said peripheral zone.

13. A method of claim 11, wherein said concave surface comprises said central optical zone, said transition zone, and said peripheral zone.

14. A method of claim 11, wherein said contact lens is a soft contact lens.

15. A series of contact lenses comprising contact lenses having different power corrections, wherein each contact lens in the series has at least one surface comprising:
    a) a central optical zone that is an aspherical sub-surface;
    b) a transition zone that is adjacent to said central optical zone, wherein the transition zone is a rotationally symmetric off-center sphere sub-surface; and
    c) a peripheral zone that comprises one or more sphere sub-surfaces,

    wherein all sub-surfaces are tangent to each other.

16. A series of contact lenses of claim 15, wherein said central optical zone is described by an aspherical function form of

$$y_{opz} = \frac{x^2}{r\left(1+\sqrt{1-\frac{1+\kappa}{r_0^2}x^2}\right)} \quad \text{or} \quad y_{opz} = a_0 + a_1 x + a_2 x^2 + \ldots + a_n x^n \qquad (1)$$

wherein r_0 is the radius at the apex of the aspherical sub-surface, κ is a conic constant, $a_0, \ldots, a_n$ are coefficient constants, and

wherein said rotationally symmetric off-center sphere surface has a curvature radius (r_a) defined by a functional form (2)

$$r_a = \frac{\left\{1+\left[y'_{opz}(x_a)\right]^2\right\}^{3/2}}{y''_{opz}(x_a)} \qquad (2)$$

wherein $y'_{opz}(x_a)$ is the 1[st] derivative of the aspherical function form (1) at a junction point $A(x_a,y_a)$ of the transition zone with the central optical zone, $y''_{opz}(x_a)$ is the 2[nd] derivative of the aspherical function form (1) at the junction point $A(x_a,y_a)$, and wherein the center $C(x_c,y_c)$ of the curvature radius r_a is given by formula (3) and (4)

$$x_c = x_a - \frac{y'_{opz}(x_a)\cdot\left\{1+\left[y'_{opz}(x_a)\right]^2\right\}}{y''_{opz}(x_a)} \qquad (3)$$

$$y_c = y_a + \frac{\left\{1+\left[y'_{opz}(x_a)\right]^2\right\}}{y''_{opz}(x_a)} \qquad (4)$$

17. A series of contact lenses of claim 16, wherein said surface is a convex surface.

18. A series of contact lenses of claim 16, wherein said surface is a concave surface.

19. A series of contact lenses of claim 16, wherein said convex surface comprises said central optical zone, said transition zone, and said peripheral zone.

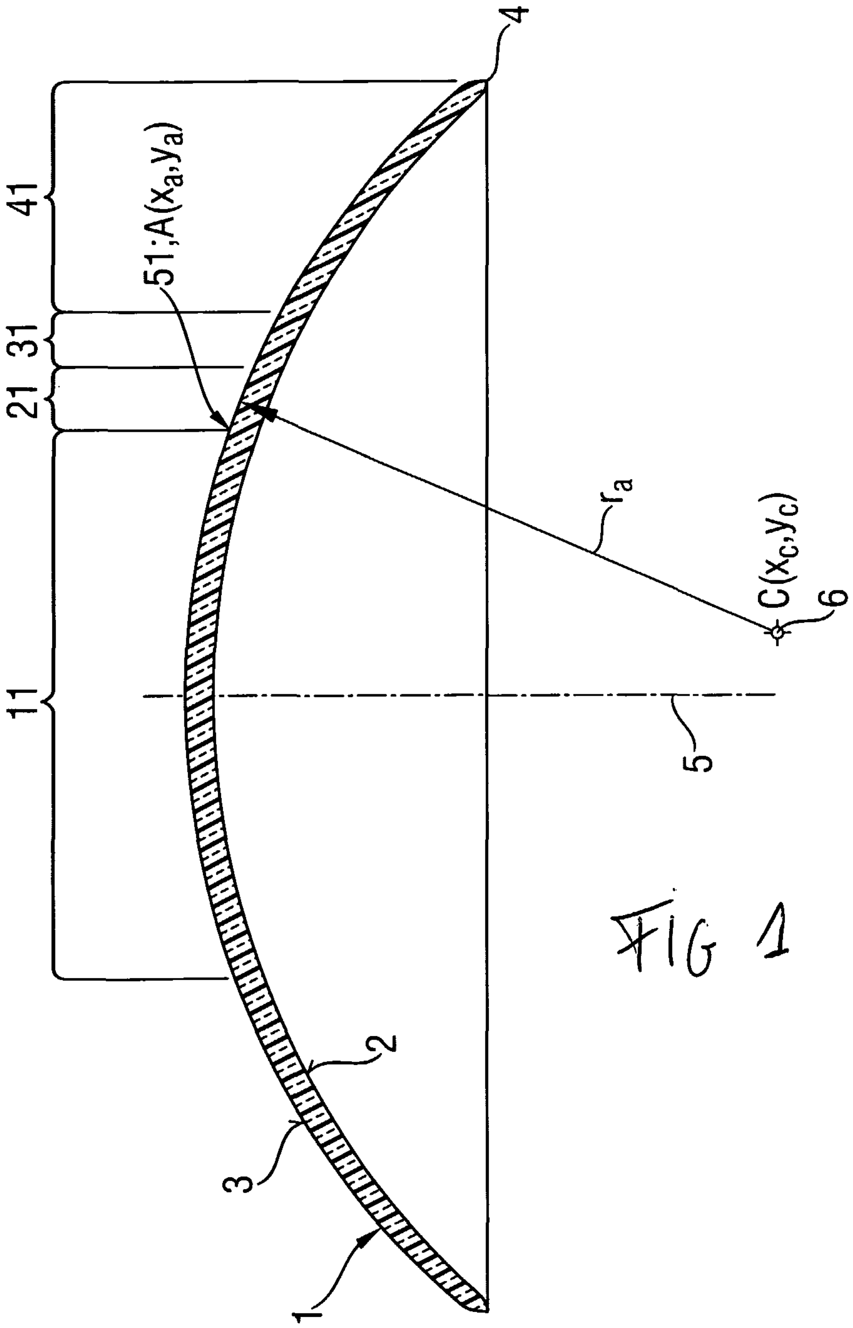

FIG 1

INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 03/01448

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 G02C7/04

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 7 G02C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 6 270 218 B1 (CLUTTERBUCK TIMOTHY A) 7 August 2001 (2001-08-07) abstract column 1, line 55 - line 59 column 2, line 19 - line 65 figures 2-5	1,2,7,9, 15
A		3-6, 8-14, 16-19

A	SCHRODER G: "Technische Optik, 2.6 ANWENDUNG ASPHAERISCHER FLAECHEN" , TECHNISCHE OPTIK. GRUNDLAGEN UND ANWENDUNGEN, WURZBURG, VOGEL BUCHVERLAG, DE, PAGE(S) 54-55 XP002222505 ISBN: 3-8023-0067-X page 54 -page 55	3,10,16

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[X] Further documents are listed in the continuation of box C.

[X] Patent family members are listed in annex.

° Special categories of cited documents :

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Date of the actual completion of the international search	Date of mailing of the international search report
23 June 2003	03/07/2003

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

International Application No
PCT/EP 03/01448

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication,where appropriate, of the relevant passages	Relevant to claim No.
A	GB 607 641 A (ARTHUR JAMES FORKNALL) 2 September 1948 (1948-09-02) page 1, line 36 - line 43 figures	1-19
A	US 5 404 183 A (SEIDNER LEONARD) 4 April 1995 (1995-04-04) column 4, line 14 - line 63 figures	1-19
A	GB 905 289 A (PLASTIC CONTACT LENS COMPANY) 5 September 1962 (1962-09-05) page 5, line 53 - line 57 figures	1-19

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No
PCT/EP 03/01448

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 6270218 B1	07-08-2001	AU 5605199 A	04-05-2000
		CN 1254103 A	24-05-2000
		KR 2000029254 A	25-05-2000
GB 607641 A	02-09-1948	NONE	
US 5404183 A	04-04-1995	CA 2253419 A1	24-07-1997
		WO 9726580 A1	24-07-1997
		EP 0937277 A1	25-08-1999
		US 5493350 A	20-02-1996
		US 5526071 A	11-06-1996
		US 5619289 A	08-04-1997
		US 5691797 A	25-11-1997
		JP 2002515132 T	21-05-2002
GB 905289 A	05-09-1962	NONE	