METHOD OF MANUFACTURING SPECTACLE LENSES

Field of the Invention

The present invention relates to ophthalmic lenses. In particular, the invention provides methods for producing a full prescriptive range of spectacle lenses while minimizing the number of the optical preforms, molds, or both required to produce the lenses.

Background of the Invention

The use of spectacle lenses for the correction of ametropia is well known. For example, multifocal lenses, such as progressive addition lenses ("PAL's"), are used for the treatment of presbyopia. The manufacture of a full range of prescriptions for spectacle lenses, particularly multifocal lenses such as PAL's, by certain methods, such as surface casting, is problematic in that it requires a large number of lens shapes. This is especially true for prescriptions that include toric, or cylindric, correction of the lens wearer's astigmatism. For example, a typical range of prescriptive lenses with toric correction may have 49 distance powers, 10 cylinder powers, 180 cylinder axes, and 9 add powers for a total of 794,241 different prescriptions. However, maintenance of such a large stock of lens shapes is impractical. Thus, a need exists for a process for producing a full prescriptive range of spectacle lenses that overcome this disadvantage.

Brief Description of the Drawings

FIG. 1 is a cross-sectional view of an embodiment of the lens of the invention.

FIG. 2 is a cross-sectional view of an embodiment of the lens of the invention.

FIG. 3 is a cross-sectional view of an embodiment of the lens of the invention.

FIG. 4 is a cross-sectional view of an embodiment of the lens of the invention.

FIG. 5 is a cross-sectional view of an embodiment of the lens of the invention.

FIG. 6 is a cross-sectional view of an embodiment of the lens of the invention.

Description of the Invention and its Preferred Embodiments

The present invention provides methods for producing spectacle lenses, including multifocal lenses such as progressive addition lenses, as well as lenses produced by the methods. The invention permits production of the full prescriptive range of lenses while reducing the number of optical preforms, molds, or both required. It is one discovery of the invention that a full prescriptive range of spectacle lenses may be produced by both minimizing the optical preform curves used and adding power onto the preform to produce the desired lens.

Thus, in one embodiment, the invention provides a method for producing a lens comprising, consisting essentially of, and consisting of the steps of: a.) providing an optical preform having a first distance power, the preform comprising, consisting essentially of, and consisting of a convex and a concave surface; and b.) adding onto at least one of the convex or concave surfaces one or more layers comprising, consisting essentially of, and consisting of a second distance power. One ordinarily skilled in the art will recognize that the distance power of the lens will be the sum of the first and second distance powers. By "optical preform" is meant a shaped, optically transparent article capable of refracting light and possessing a convex and a concave surface, which article is suitable for use in producing a spectacle lens.

In the method of the invention an optical preform is provided having a portion of the distance power of the desired lens. Additional distance power is then added in one or more layers to the preform to obtain the desired final distance prescription for the lens. It is a discovery of the invention that the manufacture of

multifocal lenses may be more efficiently accomplished by the use of an optical preform having a given distance power onto which additional distance power is added. By distributing the distance power of the final, desired lens between the preform and one or more layers added to the preform, the number of preforms, molds, or both necessary to produce a full prescriptive range of spectacle lenses is reduced in relation those used in conventional surface casting techniques.

One ordinarily skilled in the art will recognize that the distribution of distance power between the preform and layer or layers added to the preform may be any of a variety of increments. Preferably, the following preform distance powers are used with the listed base curves and added distance powers: about +2 to about + 5 with a base curve of about –1 to about –4 and added power of about 0 to about +6 diopters; about 0 to about +3 diopters with a base curve of about -2 to about –6 diopters and added power of about 0 to about +6 diopters; about –1 to about +1 diopters with a base curve of about –4 to about –6 diopters and added power of about –6 to about +6; and –1 to about –5 with a base curve of about –4 to about –9 with added power of about 0 to about –6 diopters.

It is more preferred that the distance power of the preform be selected from the following powers: about +3.50 diopters; about +1.50 diopters; about 0.00 diopters; or about –3.00 diopters. Further, it is preferred that, for these preform powers, the concave surface of the preform be of one of the following base curvatures: about -2.50 diopters; about -4.00 diopters; about -5.50 diopters; or about –7.00 diopters. Similarly, although any distance power increment may be added to the preform, it is preferred that the added layer be added onto the convex surface for the specific preform and concave surface curvature be as set forth in Table 1. All values in Table 1 are to be assumed to be proceeded by the phrase "about."

Table 1

Optical Preform Power (diopters)	Concave Surface Base Curve (diopters)	Convex Surface Added Distance Power (diopters)
+3.50 D	-2.50 D	+0.75 to +2.50 D
+1.50 D	-4.00 D	+0.50 to +2.50 D
0 D	-5.50 D	+1.75 to –2.75 D
-3.00 D	-7.00 D	0 to –3.00 D

The reason for the preference in adding only negative distance power onto a negative power preform and positive onto positive is that the addition of unnecessary thickness of the added layer and finished lens is avoided.

One ordinarily skilled in the art will recognize that any type of lens, such as single vision, flat-top, multifocal including, without limitation, bifocal, trifocal, progressive, or the like, may be produced using the method of the invention. However, the invention may find greater utility in the production of multifocal lenses, particularly progressive addition lenses. Further, the invention may find its greatest utility in the production of progressive addition lenses using surface casting. In embodiments in which the desired final lens is a bifocal, the preform, the added layer, or both must provide near vision power in addition to distance power. For embodiments in which the final lens is a PAL, the preform, layer, or both must provide near vision power, distance power and a zone of transition power between the distance and near vision power zones. For example, a surface of the preform or an added layer may be a progressive addition surface thus providing a progressive addition lens as the final lens. By "progressive addition surface" is meant a continuous, aspheric surface having distance and near vision zones and a zone of transition power, or zone of increasing dioptric power, connecting the distance and near vision zones.

In a preferred embodiment, a progressive addition lens is provided by distributing the dioptric add power of the final lens between the preform and the added layer or layers. By "dioptric add power" is meant the amount of dioptric power difference between the near and distance vision zones of a surface or lens. In such an embodiment, a portion of the dioptric add power may be on the concave surface of the preform and the remaining dioptric add power in a layer or layers added onto the convex surface of the preform. In yet another embodiment, a portion of the dioptric add power is on the convex surface of the preform and additional dioptric add power is added onto the concave surface of the preform.

In still another embodiment, the dioptric add power of the preform is distributed between the concave and convex surface of the preform and additional distance power, alone or with other power, is added onto one or both of these surfaces. In this embodiment, the preform and added layer materials must be selected so that the refractive index of the preform differs from that of the added layer by about 0.01 or greater. However, because the greater the difference in refractive indices, the greater will be a particular curvature's contribution to power, preferably the difference is about 0.05 or greater.

The total dioptric add power for the lens may be about +0.01 to about +3.50, preferably about +0.25 to about +3.50, more preferably about +1.00 to about +3.00 diopters. The total dioptric add power may be split, or distributed, between the preform and added layer or layers in a ratio of about 90:10 to about 10:90 percent, preferably about 70:30 to about 30:70 percent, more preferably about 60:40 to about 40:60 percent.

For production of progressive lenses of the invention, preferably the concave surface of the optical preform is symmetric and the convex surface of the finished lens is asymmetric. By symmetric is meant that the power and astigmatism maps of the surface are symmetric about the center meridian of the surface.

In addition to one or more of a dioptric add power, an intermediate power, a distance vision power, or both, the concave surface of the preform may have a cylinder power for correction of the lens wearer's astigmatism. By "cylinder power" is meant the difference in powers measured in the two principal meridians of a preform or a lens. The cylinder power also may be located on the convex surface of the preform or distributed between the concave or convex surface of the preform and the added layer or layers. In a preferred embodiment, the concave surface of the preform has all of the cylinder power desired for the lens. The total cylinder power for the lens may be about –0.125 to about –6.00 diopters, preferably about –0.25 to about –3.00 diopters.

One ordinarily skilled in the art will recognize that the invention encompasses any one of a number of preform and added layer combinations of distance vision power with one or one or more of dioptric add power, transition power, and cylinder power. In yet another embodiment, the invention provides a method for producing a spectacle lens comprising, consisting essentially of and consisting of: a.) providing an optical preform having a first distance power, the preform comprising, consisting essentially of, and consisting of a convex and a concave surface wherein one or both of the convex and concave surfaces has a power selected from the group consisting of dioptric add power, a zone of transition power, cylinder power, and combinations thereof; and b.) adding onto at least one of the convex or concave surfaces of the preform one or more layers comprising, consisting essentially of, and consisting of a second distance power.

In yet another embodiment, the invention provides a method for producing a spectacle lens comprising, consisting essentially of, and consisting of: a.) providing an optical preform having a first distance power, the preform comprising, consisting essentially of, and consisting of a convex and a concave surface wherein one or both of the convex and concave surfaces has a power selected from the group consisting of a first dioptric add power, a first zone of transition power, a first cylinder power,

and combinations thereof; and b.) adding onto at least one of the convex or concave surfaces one or more layers comprising, consisting essentially of, and consisting of a second distance power and a power selected from the group consisting of a second dioptric add power, a second zone of transition power, a second cylinder power, and combinations thereof.

In cases in which the concave surface of the preform and one or more added layer form progressive surfaces and the concave surface also has cylinder power, the preforms required for such a combination may be reduced further by limiting the dioptric add power location to eight orientations relative to the cylinder axis. In this case a dioptric add power is not provided for every cylinder axis combination. Rather, because it was discovered that the dioptric add power decreases relatively slowly when one moves horizontally away from the center of the near vision zone to the lens periphery, a rotational misalignment of the near vision zone of the concave surface relative to that of the added layer of about + or – 1 to about + or – 25, preferably + or – 1 to about + or – 20, more preferably + or – 1 to about + or – 15 degrees may be used.

The optical preforms useful in the invention may be made of any suitable materials. Examples of suitable materials include, without limitation, polycarbonates, such as bisphenol A polycarbonates, allyl diglycol carbonates, such as diethylene glycol bisallyl carbonate (CR-39™), allylic esters, such as triallyl cyanurate, triallyl phosphate and triallyl citrate, acrylic esters, acrylates, methacrylates, such as methyl- ethyl- and butyl methacrylates, styrenics, polyesters, and the like and combinations thereof. The preform may be produced by any convenient means including, without limitation, injection molding, injection-compression molding, thermoforming, casting, or the like.

The added distance power, dioptric add power, transition power, and cylinder power may be added by any convenient method. Suitable methods for

adding one or more layers onto the preform include, without limitation, casting, surface casting, coating, thermoforming, injection molding and the like. Preferably the added layer or layers are surface cast onto the preform. Surface casting of the layer or layers onto the preform may be accomplished by any known method. Suitable methods for casting the convex and concave surfaces of a preform are disclosed in United States Patent Nos. 5,147,585, 5,178,800, 5,219,497, 5,316,702, 5,358,672, 5,480,600, 5,512,371, 5,531,940, 5,702,819, and 5,793,465 incorporated herein in their entireties by reference.

The added layer or layers of distance power may be of a total thickness of less than about 1 mm, preferably less than about 0.25 mm, more preferably less than about 0.1 mm. One ordinarily skilled in the art will recognize that the point for measuring the thickness of the layer or layers varies depending on whether the lens is a plus or minus lens. By "plus lens" is meant that the lens is thicker in the center than at its edges and by "minus lens" is meant that the lens is thinner at its center than at its edges. For a minus lens, the appropriate point to measure the thickness of the added layer will be at the center of the lens. For plus lenses, the point for measuring thickness will be at the lens edge.

The invention will be clarified by considering the following, non-limiting examples.

Examples

Example 1

A polycarbonate preform is formed by injection molding. Referring to FIG. 1, preform 1 has a concave surface 2 base curvature of –5.50 diopters and a convex surface 3 base curvature of 5.50 diopters resulting in a preform distance power of 0 diopters. A layer 4 is surface cast onto preform 1, the cast layer 4 having a curvature of 3.00 diopters in the distance zone 5 and a 5.00 diopters curvature in the add, or near vision, zone 6 and a zone of transition power 7 between the distance and add

zones. The resulting lens 10 has a distance power of –2.50 diopters and a dioptric add power of +2.00.

Example 2

Referring to FIG. 2, the procedure of Example 1 is followed except that preform concave surface 8 additionally has a –2.00 diopters cylinder power at 180° and a 7.50 diopters cylinder curvature 9. The added layer 11 is the same as for Example 1, the resulting lens 20 having a distance power of –2.50 diopters with –2.00 diopters of cylinder and a dioptric add power of +2.00.

Example 3

Referring to FIG. 3, the procedure of Example 1 is used except that the preform 12 has a distance power of –3.00 diopters. Preform 12 has a -7.00 diopters concave surface 13 and a 4.00 diopters convex surface 14 resulting in a distance power of –3.00 diopters. The distance power of the added layer 15 is –3.00 diopters with a dioptric add power of +2.00. The resulting lens 30 has a distance power of –6.00 diopters and a dioptric add power of +2.00.

Example 4

Referring to FIG. 4, the procedure of Example 3 is used except that preform 17 has a distance power of +3.50 diopters resulting from a -2.50 concave and +6.00 diopters convex surface distance curvatures. Added layer 18 has a distance power of +2.50 diopters with a dioptric add power of +2.00. The resulting lens 40 has a distance power of +6.00 diopters and a dioptric add power of +2.00.

Example 5

Referring to FIG. 5, a polycarbonate preform is injection molded. Preform 19 has a -5.50 diopters concave surface 21 distance curvature with a - 4.50 diopters add zone 22 and a transition power zone 23. Convex surface 24 has 5.50 diopters distance power resulting in a first distance power of 0 diopters and a dioptric add

power of 1.00. Added layer 25 is surface cast onto preform 19. Layer 25 has a distance zone 26 curvature of 3.00 diopters and a 4.00 diopters curvature in add zone 27. The resulting lens 50 has a distance power of –2.50 diopters and a dioptric add power of +2.00.

Example 6

A polycarbonate preform, having a refractive index of 1.59, is injection molded. Referring to FIG. 6, preform 29 has a dioptric add power spilt between the convex and concave surfaces and distance power of +4.50 diopters. Concave surface 31 also has a dioptric add power of 1.50 diopters and convex surface 32 has a dioptric add power of 1.75. Added layer 33 is cast onto preform 29. The index of refraction for layer 33 is 1.50. The dioptric add power of the finished lens 60 is +2.00, the result of a +1.75 diopters contribution from convex surface 32 and a +1.50/6, or +0.25, diopters contribution from concave surface 31 when combined with layer 33. Layer 33 has a distance power of +1.50 diopters. The resulting lens 60 has a distance power of +6.00 diopters and a dioptric add power of +2.00 diopters.

What is claimed is:

1. A method for producing a spectacle lens comprising the steps of:

a.) providing an optical preform having a first distance power, the preform comprising a convex surface and a concave surface; and

b.) adding onto at least one of the convex or concave surfaces one or more layers comprising a second distance power.

2. The method of claim 1, wherein step b.) is performed by surface casting the one or more layers onto the preform.

3. The method of claim 2, wherein the first distance power is about +2 to about + 5 with a base curve of about –1 to about –4; about 0 to about +3 diopters with a base curve of about -2 to about –6 diopters; about –1 to about +1 diopters with a base curve of about –4 to about –6 diopters; or –1 to about –5 with a base curve of about –4 to about –9.

4. The method of claim 3, wherein the second distance power for each of the first distance powers is about 0 to about +6 diopters, about 0 to about +6 diopters, about –6 to about +6, or about 0 to about –6 diopters, respectively.

5. A method for producing a spectacle lens comprising the steps of:

a.) providing an optical preform having a first distance power, the preform comprising a convex surface and a concave surface wherein one or both of the convex and concave surfaces has a power selected from the group consisting of a dioptric add power, a zone of transition power, a cylinder power, and combinations thereof; and

b.) adding onto at least one of the convex or concave surfaces of the preform one or more layers comprising a second distance power.

6. The method of claim 5, wherein step b.) is performed by surface casting the one or more layers onto the preform.

7. The method of claim 6, wherein the first distance power is about +2 to about + 5 with a base curve of about –1 to about –4; about 0 to about +3 diopters with a base curve of about -2 to about –6 diopters; about –1 to about +1 diopters with a base curve of about –4 to about –6 diopters; or –1 to about –5 with a base curve of about –4 to about –9.

8. The method of claim 7, wherein the second distance power for each of the first distance powers is about 0 to about +6 diopters, about 0 to about +6 diopters, about –6 to about +6, or about 0 to about –6 diopters, respectively.

9. The method of claim 5, wherein the one or both of the convex and concave surfaces comprises the dioptric add power.

10. The method of claim 5, wherein the one or both concave and convex surfaces comprises the dioptric add power and the zone of transition power.

11. The method of claim 5, wherein the one or both of the convex and concave surfaces comprises the cylinder power.

13. The method of claim 5, wherein the one or both of the convex and concave surfaces comprises the dioptric add power and a cylinder power.

14. The method of claim 13, wherein one or both of the concave and convex surfaces further comprise the zone of transition power.

15. A method for producing a multifocal spectacle lens comprising:

a.) providing an optical preform having a first distance power, the preform comprising a convex surface and a concave surface wherein one or both of the convex and concave surfaces has a power selected from the group consisting of a first dioptric add power, a first zone of transition power, a first cylinder power, and combinations thereof; and

b.) adding onto at least one of the convex or concave surfaces one or more layers comprising a second distance power and a power selected from the group consisting of a second dioptric add power, a second zone of transition power, a second cylinder power, and combinations thereof.

16. The method of claim 15, wherein step b.) is performed by surface casting the one or more layers onto the preform.

17. The method of claim 16, wherein the first distance power first distance power is about +2 to about + 5 with a base curve of about –1 to about –4; about 0 to about +3 diopters with a base curve of about -2 to about –6 diopters; about –1 to about +1 diopters with a base curve of about –4 to about –6 diopters; or –1 to about –5 with a base curve of about –4 to about –9.

18. The method of claim 17, wherein the second distance power for each of the first distance powers is about 0 to about +6 diopters, about 0 to about +6 diopters, about –6 to about +6, or about 0 to about –6 diopters, respectively.

19. The method of claim 15 wherein the preform concave surface comprises the first dioptric add power, the first zone of transition power and the first cylinder power and the one or more added layers is added onto the convex surface, the one or more added layers comprising the second dioptric add power.

20. The method of claim 19, wherein the one or more added layers further comprises the second zone of transition power.

21. The method of claim 19, wherein the concave surface further comprises a near vision zone and the one or more added layers further comprises a near vision zone, the concave surface near vision zone being rotationally misaligned about + or – 1 to about + or – 25 degrees in relation to the one or more added layers near vision zone.

22. A method for producing a progressive addition spectacle lens comprising:

a.) providing an optical preform having a first distance power of about +2 to about + 5 with a concave surface base curve of about –1 to about –4; about 0 to about +3 diopters with a concave base curve of about -2 to about –6 diopters; about –1 to about +1 diopters with a concave surface base curve of about –4 to about –6 diopters; or –1 to about –5 with a concave surface base curve of about –4 to about –9, the preform comprising a first dioptric add power and a first zone of transition power; and

b.) surface casting onto the convex surface one or more layers comprising a second distance power, a second dioptric add power, and a second zone of transition power.

23. The method of claim 22, wherein the second distance power for each of the first distance powers is about 0 to about +6 diopters, about 0 to about +6 diopters, about –6 to about +6, or about 0 to about –6 diopters, respectively.

24. The method of claim 22, wherein the concave surface further comprises a first cylinder power

25. The method of claim 24, wherein the concave surface further comprises a near vision zone and the one or more added layers further comprises a near vision zone, wherein the concave surface near vision zone is rotationally misaligned about + or – 1 to about + or – 25 degrees in relation to the one or more added layers near vision zone.

26. The lens produced by the method of claim 1.



27. The lens produced by the method of claim 5.

28. The lens produced by the method of claim 15.

29. The lens produced by the method of claim 22.