

FLUID FILLED LENSES AND MECHANISMS OF INFLATION THEREOF

CROSS REFERENCE TO RELATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Patent Application No. 61/251,819, filed October 15, 2009, which is incorporated herein by reference in its entirety.

BACKGROUND

Field

[0002] Embodiments of the present invention relate to fluid-filled lenses and in particular to variable fluid-filled lenses.

Background Art

[0003] Basic fluid lenses have been known since about 1958, as described in U.S. Pat. No. 2,836,101, incorporated herein by reference in its entirety. More recent examples may be found in "Dynamically Reconfigurable Fluid Core Fluid Cladding Lens in a Microfluidic Channel" by Tang et al., Lab Chip, 2008, vol. 8, p. 395, and in WIPO publication WO2008/063442, each of which is incorporated herein by reference in its entirety. These applications of fluid lenses are directed towards photonics, digital phone and camera technology and microelectronics.

[0004] Fluid lenses have also been proposed for ophthalmic applications (see, e.g., U.S. Patent No. 7,085,065, which is incorporated herein by reference in its entirety). In all cases, the advantages of fluid lenses, such as a wide dynamic range, ability to provide adaptive correction, robustness, and low cost have to be balanced against limitations in aperture size, possibility of leakage, and consistency in performance. The '065 patent, for example, has disclosed several improvements and embodiments directed towards

effective containment of the fluid in the fluid lens to be used in ophthalmic applications, although not limited to them (see, e.g., U.S. Patent No. 6,618,208, which is incorporated by reference in its entirety). Power adjustment in fluid lenses has been effected by injecting additional fluid into a lens cavity, by electrowetting, application of ultrasonic impulse, and by utilizing swelling forces in a cross-linked polymer upon introduction of a swelling agent such as water.

BRIEF SUMMARY

[0005] In an embodiment, an actuator for a fluid-filled lens comprises: a housing; a reservoir disposed within the housing; a compression arm having a first end that is fixed and a second end that is not fixed, wherein the compression arm is disposed adjacent to the reservoir; and wherein the compression arm flexes to compress the reservoir.

[0006] In another embodiment, an actuator for a fluid-filled lens comprises: a housing having a first end and a second end; a reservoir disposed within the housing; and a slider slidably disposed within the housing and disposed adjacent to the reservoir, wherein the slider includes a first end having a wedge shape configured to compress the reservoir, and wherein sliding of the slider from the second end of the housing to the first end of the housing causes the first end of the slider to compress the reservoir.

[0007] Further embodiments, features, and advantages of the present invention, as well as the structure and operation of the various embodiments of the present invention, are described in detail below with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS/FIGURES

[0008] The accompanying drawings, which are incorporated herein and form a part of the specification, illustrate the present invention and, together with the description, further serve to explain the principles of the invention and to enable a person skilled in the pertinent art to make and use the invention.

[0009] FIG. 1 illustrates a perspective view of an embodiment of a caliper actuator assembly.

- [0010] FIG. 2 illustrates an exploded perspective view of an embodiment of a caliper actuator assembly.
- [0011] FIG. 3 illustrates a first set of steps for assembling an embodiment of a slider subassembly.
- [0012] FIG. 4 illustrates a second set of steps for assembling an embodiment of a slider subassembly.
- [0013] FIG. 5 illustrates a set of steps for assembling an embodiment of a temple cover subassembly.
- [0014] FIG. 6 illustrates a set of steps for assembling an embodiment of a compression arm subassembly.
- [0015] FIG. 7 illustrates a first set of steps for assembling an embodiment of a temple chassis subassembly.
- [0016] FIG. 8 illustrates a second set of steps for assembling an embodiment of a temple chassis subassembly.
- [0017] FIG. 9 illustrates a set of steps for assembling an embodiment of a temple subassembly.
- [0018] FIG. 10 illustrates a set of steps for assembling an embodiment of a lens module subassembly.
- [0019] FIG. 11 illustrates a perspective view of a portion of an embodiment of a caliper actuator assembly.
- [0020] FIG. 12 shows an embodiment of a caliper actuator assembly.
- [0021] FIG. 13 shows an embodiment of a caliper actuator assembly.
- [0022] FIG. 14 shows an embodiment of a caliper actuator assembly with a portion of the temple cover removed.
- [0023] FIG. 15 illustrates a portion of an embodiment of a caliper actuator assembly.
- [0024] FIG. 16 shows charts with data corresponding to breadboard actuator performance for an embodiment of a caliper actuator assembly.
- [0025] FIG. 17a illustrates an embodiment of a caliper actuator assembly.
- [0026] FIG. 17b illustrates an embodiment of a caliper actuator assembly.
- [0027] FIG. 18 shows charts with data corresponding to breadboard actuator performance for embodiments of a caliper actuator assembly.

- [0028] FIG. 19a illustrates a side view of an embodiment of a roll and translate actuator assembly.
- [0029] FIG. 19b illustrates a top view of the roll and translate actuator assembly of FIG. 19a.
- [0030] FIG. 19c illustrates a side view of the roll and translate actuator assembly of FIG. 19a when compressed.
- [0031] FIG. 20a illustrates a side view of another embodiment of a roll and translate actuator assembly.
- [0032] FIG. 20b illustrates a top view of the roll and translate actuator assembly of FIG. 20a.
- [0033] FIG. 20c illustrates a side view of the roll and translate actuator assembly of FIG. 20a when compressed.
- [0034] FIG. 21a illustrates a side perspective view of an embodiment of a reservoir.
- [0035] FIG. 21b illustrates a front view of an embodiment of a reservoir.
- [0036] FIG. 21c illustrates a front view of an embodiment of a reservoir when compressed.
- [0037] FIG. 22a illustrates a side view of an embodiment of a rack and pinion actuator assembly.
- [0038] FIG. 22b illustrates a side view of the rack and pinion actuator assembly of FIG. 22a when compressed.
- [0039] FIG. 23a illustrates a side view of an embodiment of a rack and pinion actuator assembly.
- [0040] FIG. 23b illustrates a top view of the rack and pinion actuator assembly of FIG. 23a.
- [0041] FIG. 22c illustrates a side view of the rack and pinion actuator assembly of FIG. 23a when compressed.
- [0042] FIG. 24 illustrates a front perspective exploded view of an embodiment of a rack and pinion actuator assembly.
- [0043] FIG. 25 shows an embodiment of a rack and pinion actuator assembly.
- [0044] FIG. 26 illustrates a portion of an embodiment of a rack and pinion actuator assembly.
- [0045] FIG. 27a illustrates a side view of an embodiment of a screw actuator assembly.

- [0046] FIG. 27b illustrates a side view of an embodiment of a screw actuator assembly when compressed.
- [0047] FIG. 28a illustrates a side view of an embodiment of a rotation actuator assembly when partially compressed.
- [0048] FIG. 28b illustrates a view of an embodiment of the rotation actuator assembly of FIG. 28a along line A.
- [0049] FIG. 29a illustrates a side view of an embodiment of a slide and translate actuator assembly.
- [0050] FIG. 29b illustrates a front sectional view of an embodiment of a slide and translate actuator assembly.
- [0051] Embodiments of the present invention will be described with reference to the accompanying drawings.

DETAILED DESCRIPTION

- [0052] Although specific configurations and arrangements are discussed, it should be understood that this is done for illustrative purposes only. A person skilled in the pertinent art will recognize that other configurations and arrangements can be used without departing from the spirit and scope of the present invention. It will be apparent to a person skilled in the pertinent art that this invention can also be employed in a variety of other applications.
- [0053] It is noted that references in the specification to "one embodiment," "an embodiment," "an example embodiment," etc., indicate that the embodiment described may include a particular feature, structure, or characteristic, but every embodiment may not necessarily include the particular feature, structure, or characteristic. Moreover, such phrases do not necessarily refer to the same embodiment. Further, when a particular feature, structure or characteristic is described in connection with an embodiment, it would be within the knowledge of one skilled in the art to effect such feature, structure or characteristic in connection with other embodiments whether or not explicitly described.
- [0054] Fluid lenses have important advantages over conventional means of vision correction, such as rigid lenses and contact lenses. First, fluid lenses are easily adjustable. Thus, a presbyope who requires an additional positive power correction to view near

objects can be fitted with a fluid lens of base power matching the distance prescription. The user can then adjust the fluid lens to obtain additional positive power correction as needed to view objects at intermediate and other distances.

[0055] Second, fluid lenses can be adjusted continuously over a desired power range by the wearer. As a result, the wearer can adjust the power to precisely match the refractive error for a particular object distance in a particular light environment. Thus, fluid lenses allow adjustment of power to compensate for alteration of the natural depth of focus of the eye that depends on the wearer's pupil size, which is in turn dependent on the ambient light level.

[0056] Third, although 20/20 vision, which corresponds to an image resolution of 1 minute of arc (1/60 degree) is generally acknowledged to represent an acceptable quality of vision, the human retina is capable of finer image resolution. It is known that a healthy human retina is capable of resolving 20 seconds of arc (1/300 degree). Corrective eyeglasses designed to enable a patient to achieve this superior level of vision have a resolution of about 0.10D or better. This resolution can be achieved with continuously adjustable fluid lens elements.

[0057] In an embodiment of a fluid lens assembly, one or more fluid lenses may be provided with its own actuation system, so that a lens for each eye can be adjusted independently. This feature allows wearers, such as anisometropic patients, to correct any refractive error in each eye separately, so as to achieve appropriate correction in both eyes, which can result in better binocular vision and binocular summation.

[0058] FIG. 1 illustrates a perspective view of a caliper actuator assembly 100, according to an embodiment of the present invention. Caliper actuator assembly 100 includes temple cover 110, which includes a hollow outer portion and a hollow inner portion formed together to enclose additional pieces of caliper actuator assembly 100. Distal end 160 of temple cover 110 is shaped to fit over a wearer's ear. Caliper actuator assembly 100 further includes temple chassis 120, wheel 130, and slider 140. In an embodiment, wheel 130 and slider 140 are longitudinally slidably disposed within temple chassis 120. Caliper actuator assembly 100 operates to compress reservoir 150 and transfer fluid between reservoir 150 and a fluid lens (not shown). The compressing force may be applied in various ways, such as for example, by rotating wheel 130 or by translating the wheel along a slot. Additional methods of applying compressing force are also described

herein. The compression of reservoir 150 may be effected either by compressing reservoir 150 in a vertical or horizontal direction against a ceiling or inner wall of temple chassis 120, as described in detail below.

[0059] FIG. 2 illustrates an exploded perspective view of an embodiment of caliper actuator assembly 100. In an embodiment, slider subassembly 295 (described below with respect to FIGs. 3-4) is configured to translate along one or more of temple cover 110 and temple chassis 120 in order to compress reservoir 150. In operation, a user rotates wheel 130, which moves slider block 255, which in turn compresses a relatively stiff metal plate, such as compression arm 270, that is in contact with a first side surface 265 of reservoir 150. A second side surface (not shown) of reservoir 150 is placed against inner wall 285 of temple chassis 120, a portion of temple cover 110, or any other suitable surface. Slider 140 presses against compression arm 270, which compresses reservoir 150 in a controllable manner. In an embodiment, the length of the lateral movement of wheel 130 is proportional to the magnitude of compression of the compression arm, and is proportional to the magnitude of compression of the reservoir.

[0060] In an embodiment, wheel 130 has a knurled edge in order to provide secure contact with the finger of the user as well more precise control over the translation of wheel 130.

[0061] Lens module 200 is connected via outlet port 245 to a connecting tube (not shown), which is connected to reservoir 150. Lens module 200 may further include a flexible back surface provided by, for example, a flexible membrane (not shown) stretched flat over the edge of a rigid optical lens. To change the optical power of fluid filled lens module 200, the membrane may be inflated through the addition of a fluid from reservoir 150.

[0062] The connecting tube delivers fluid from lens module 200 to reservoir 150 and vice versa. The connecting tube is designed to be relatively impermeable to the fluid contained therein. In an embodiment, the connecting tube is configured to allow a minimum flow rate at all times in order to ensure a minimum speed of response to the user moving wheel 130 in order to change the optical power of fluid filled lens module 200. The connecting tube is connected at one end to outlet port 245 of lens module 200 and at the other end to reservoir 150. In an embodiment, the overall assembly including the lens module 200, the connecting tube, and reservoir 150 is designed to maintain a seal

excluding fluids and air for an overall use period of two years or more. In an embodiment, the connecting tube is thin in order to be accommodated within a hinge cavity. In an embodiment, it is less than 2.0 mm in outer diameter and less than 0.50 mm in wall thickness, in order to maintain an adequate flow of fluid. In an embodiment, it is capable of being bent by an angle of no less than 60 degrees. In an embodiment, it is capable of being bent by an angle of no less than 45 degrees without crimping. In an embodiment, it is durable to repeated flexing of the hinge.

[0063] Hinge block 250 and spring 230 are enclosed within a covered area between inner block 210 and outer block 240. Additional embodiments of the hinge and spring are described in U.S. Appl. No. 12/904,769. Caliper actuator assembly 100 includes wheel 130 held in place by axle 280, slider 140, slider block 255, spacer block 290, and compression arm 270. These parts are assembled into a temple chassis subassembly (which is described further with respect to FIGS. 7 and 8) and are held in place by screws 235. Rubber strip 205 includes a flexible surface upon which wheel 130 may move. In an embodiment, wheel 130 may rotate. In another embodiment it may translate, and in yet another embodiment it may rotate and translate.

[0064] In an embodiment, slider 140 maintains reservoir 150 in its compressed state as it moves away from distal end 160. As slider 140 is moved towards distal end 160, the compressing force on reservoir 150 is released, and reservoir 150 springs back to its original shape, temporarily creating low pressure on the fluid, and thus pulling fluid back from lens module 200.

Materials

[0065] The pieces of the various actuator assemblies described herein, for example, but not limited to, the temple cover, temple chassis, wheel, slider, spring, screws, inner block, outer block, axle, compression arm, spacer block, etc, may be manufactured through any suitable process, such as metal injection molding (MIM), cast, machining, plastic injection molding, and the like. The choice of materials may be further informed by the requirements of mechanical properties, temperature sensitivity, optical properties such as dispersion, moldability properties, or any other factor apparent to a person having ordinary skill in the art.

- [0066] The fluid used in the fluid lens may be a colorless fluid, however, other embodiments include fluid that is tinted, depending on the application, such as if the intended application is for sunglasses. One example of fluid that may be used is manufactured by Dow Corning of Midland, MI, under the name "diffusion pump oil," which is also generally referred to as "silicone oil."
- [0067] The fluid lens may include a rigid optical lens made of glass, plastic, or any other suitable material. Other suitable materials include, for example and without limitation, Diethylglycol bisallyl carbonate (DEG-BAC), poly(methyl methacrylate) (PMMA), and a proprietary polyurea complex, trade name TRIVEX (PPG).
- [0068] The fluid lens may include a membrane made of a flexible, transparent, water impermeable material, such as, for example and without limitation, clear and elastic polyolefins, polycycloaliphatics, polyethers, polyesters, polyimides and polyurethanes, for example, polyvinylidene chloride films, including commercially available films, such as those manufactured as MYLAR or SARAN. Other polymers suitable for use as membrane materials include, for example and without limitation, polysulfones, polyurethanes, polythiourethanes, polyethylene terephthalate, polymers of cycloolefins and aliphatic or alicyclic polyethers.
- [0069] The connecting tube may be made of one or more materials such as TYGON (polyvinyl chloride), PVDF (Polyvinylidene fluoride), and natural rubber. For example, PVDF may be suitable based on its durability, permeability, and resistance to crimping.
- [0070] The temple cover may be any suitable shape, and may be made of plastic, metal, or any other suitable material. In an embodiment, the temple cover is made of a lightweight material such as, for example and without limitation, high impact resistant plastics material, aluminum, titanium, or the like. In an embodiment, the temple cover may be made entirely or partly of a transparent material.
- [0071] The reservoir may be made of, for example and without limitation, Polyvinylidene Difluoride, such as Heat-shrink VITON®, supplied by DuPont Performance Elastomers LLC of Wilmington, DE, DERAY- KYF 190 manufactured by DSG-CANUSA of Meckenheim, Germany (flexible), RW-175 manufactured by Tyco Electronics Corp. of Berwyn, PA (formerly Raychem Corp.) (semirigid), or any other suitable material. Additional embodiments of the reservoir are described in U.S. Appl. No. 12/904,736.

Assembly

- [0072] FIGS. 3-4 illustrate a set of steps for assembling an embodiment of slider subassembly 295. Beginning with FIG. 3, axle 280 is first placed within hole 297 located in the center of wheel 130. Next, slider 140 is placed onto axle 280 with slider tab 310 on the same side of slider 140 as wheel 130. Next, slider 140 is laser welded to axle 280. The slider subassembly continues with FIG. 4, which illustrates a second set of steps for assembling an embodiment of the slider subassembly. Slider block 255 is assembled to slider 140 by snapping and pressing various tabs 410 protruding from slider block 255 into corresponding slots 420 located in slider 140.
- [0073] FIG. 5 illustrates a set of steps for assembling an embodiment of a temple cover subassembly 500. First, an adhesive (not shown) is applied to rubber strip 205. Although strip 205 is referred to herein as a rubber strip, one of skill in the art will recognize that strip 205 may be made from any elastic or semi-elastic material. Next, rubber strip 205 is applied to ramped surface 510 of temple cover 110. Next, wheel 130 of slider subassembly 295 is inserted into corresponding slot 520 of temple cover 110. Friction between rubber strip 205 and wheel 130 allows wheel 130 to rotate around axle 280 while translating within temple cover 110.
- [0074] FIG. 6 illustrates a set of steps for assembling compression arm subassembly 263, according to an embodiment of the present invention. First, backing 260 is placed onto compression arm 270. Next backing 260 is laser welded to compression arm 270.
- [0075] FIGS. 7-8 illustrate a set of steps for assembling an embodiment of a temple chassis subassembly. Beginning with FIG. 7, spacer block 290 is placed onto temple chassis 120. Next, spacer block 290 is welded onto temple chassis 120 along edges 710 and 720. Next, hinge block 250 is placed onto temple chassis 120. Next, hinge block 250 is welded onto temple chassis 120 along edges 730 and 740. The temple chassis subassembly continues with FIG. 8, which illustrates a second set of steps for assembling an embodiment of temple chassis subassembly 800. A backing (not shown) may be removed from tape 810 on both sides of reservoir 150. Reservoir 150 is placed against temple chassis 120. Compression arm 270 is then placed onto spacer block 290. Compression arm 270 is then welded onto spacer block 290.

- [0076] FIG. 9 illustrates a set of steps for assembling temple subassembly 900, according to an embodiment. First, tabs 920 of temple chassis subassembly 800 are slid into rear slot 930 of temple cover 110. Next, temple chassis subassembly 800 is rotated within temple cover 110 until it snaps into place. It is recommended that slider subassembly 295 be positioned as far distally as possible within temple cover 110. Further, it is recommended that when snapping temple chassis subassembly 800 into temple cover 110, tube 940 does not become pinched between hinge block 250 and temple cover 110 or temple chassis subassembly 800.
- [0077] FIG. 10 illustrates a set of steps for assembling lens module subassembly 1000, according to an embodiment. First, a suitable piece of 2-sided tape 1010 is applied on an outward facing side of reservoir 150. This process is repeated for the opposite side of reservoir 150. The backing of tape 1010 is then removed when lens module subassembly 1000 is in position within caliper actuator assembly 100.
- [0078] FIG. 11 is a perspective view of a portion of an embodiment of caliper actuator assembly 100. FIG. 12 shows an embodiment of caliper actuator assembly 100. FIG. 13 shows additional views of an embodiment of caliper actuator assembly 100. FIG. 14 shows an embodiment of caliper actuator assembly 100 with a portion of temple cover 110 removed to show temple chassis subassembly 800.
- [0079] FIG. 15 illustrates a portion of an embodiment of a caliper actuator assembly, showing the rotation of the wheel with respect to the temple cover.
- [0080] FIG. 16 shows charts with data corresponding to breadboard actuator performance for an embodiment. The charts show the changes in optical power of a fluid lens module connected to a reservoir in contact with an actuator, according to an embodiment. The charts show optical power at the optical center of the exemplary lens as a function of the position of the wheel within the slot with respect to diopter readings S , C , and $D+0.5C$. The linearity in response demonstrates that a wearer of an embodiment of the fluid-filled lenses will be able to achieve the desired level of correction by adjusting the location of the wheel within the slot.
- [0081] FIG. 17a and 17b illustrate two embodiments of caliper actuator assemblies wherein the position of slider block 255 is changed in order to shorten the length of the lever arm. FIG. 18 shows charts with data corresponding to breadboard actuator performance between the embodiments of FIGS. 17a and 17b. The charts show the

reversibility of optical power in an exemplary fluid lens module with respect to diopter readings S , C , and $D+0.5C$. The data shows that while the changes in optical power are reversible, the rate of change is variable, and depends on the initial location of the wheel within the slot. This data indicates that reversibility of the fluid lens module is improved with increased stiffness of the compression arm. However, as would be apparent to one having ordinary skill in the art, less stiff compression arms may also have beneficial properties.

[0082] Additional embodiments of actuators will now be described. Similarly to the caliper actuator embodiments described above, each of the following actuator embodiments serve to compress a reservoir located in one or more temples of a fluid-filled lens assembly in order to adjust the optical power of a fluid-filled lens.

[0083] FIG. 19a illustrates a side view of an embodiment of roll and translate actuator 1900 with vertical compression of reservoir 1930. Roll and translate actuator 1900 includes wheel 1910, slider 1920, reservoir 1930, and temple chassis 1940. In roll and translate actuator 1900, wheel 1910 translates along track 1960. Slider 1920 slides with wheel 1910 and compresses reservoir 1930 against temple chassis ceiling 1950 of temple chassis 1940. FIG. 19b illustrates a top view of the roll and translate actuator of FIG. 19a. FIG. 19c illustrates a side view of the roll and translate actuator of FIG. 19a when compressed.

[0084] FIG. 20a illustrates a side view of an embodiment of roll and translate actuator 2000 with horizontal compression of reservoir 2030. Roll and translate actuator 2000 includes wheel 2010, slider 2020, reservoir 2030, and temple chassis 2040. In roll and translate actuator 2000, wheel 2010 translates along temple chassis 2040. Slider 2020 slides with wheel 2010 and compresses reservoir 2030 against a vertical inner side surface 2050 of temple chassis 2040. In an embodiment, slider 2020 includes a wedge 2060 to facilitate the horizontal compression of reservoir 2030. FIG. 20b illustrates a top view of the roll and translate actuator of FIG. 20a. FIG. 20c illustrates a side view of the roll and translate actuator of FIG. 20c when compressed.

[0085] FIG. 21a is a side perspective view of reservoir 2030 of FIG. 20a. FIG. 21b illustrates a front view of reservoir 2030 of FIG. 20a. FIG. 21c illustrates a front view of reservoir 2030 when horizontally compressed.

[0086] FIG. 22a illustrates a front view of an embodiment of a rack and pinion actuator assembly 2200, according to an embodiment of the present invention. Rack and pinion actuator assembly 2200 includes slider bar 2270, rack portion 2210 of slider bar 2270, pinion 2220, wheel 2230, temple cover 2240, and reservoir 2260. Wheel 2230 and pinion 2220 are coupled together so that when wheel 2230 is rotated, pinion 2220 is also rotated. Teeth 2225 of pinion 2220 engage with teeth 2215 of rack portion 2210 of slider bar 2270. As a result, when wheel 2230 is rotated, slider bar 2270 moves to compress reservoir 2260 against temple chassis ceiling 2255 of temple chassis 2250. FIG. 22b illustrates a side view of the rack and pinion actuator assembly of FIG. 22a when compressed.

[0087] FIGs. 23a-c and 24 illustrate an embodiment of rack and pinion actuator assembly 2300 with horizontal compression of reservoir 2360. FIG. 23a illustrates a side view of rack and pinion actuator assembly 2300. Wheel 2330 and pinion 2320 are coupled together so that when wheel 2330 is rotated, pinion 2320 is also rotated. Teeth 2325 of pinion 2320 engage with teeth 2310 of slider bar 2370. When wheel 2330 of rack and pinion actuator assembly 2300 is rotated, slider bar 2370 compresses reservoir 2360 against a vertical inner side surface 2340 of temple chassis 2350. In an embodiment, slider bar 2370 includes a wedge 2380 to facilitate the horizontal compression of reservoir 2030. FIG. 23b illustrates a top view of the rack and pinion actuator assembly of FIG. 23a. FIG. 23c illustrates a side view of the rack and pinion actuator assembly of FIG. 23a when compressed.

[0088] FIG. 24 illustrates a perspective exploded view of an embodiment of rack and pinion actuator assembly 2400. When wheel 2430 of rack and pinion actuator assembly 2400 is rotated, slider bar 2470 pushes stiff plate 2490. Reservoir 2460 is placed between stiff plate 2490 and inner wall 2410 of temple cover 2440 so that reservoir 2460 is compressed when wheel 2430 is rotated.

[0089] FIG. 25 shows an embodiment of a rack and pinion actuator assembly. FIG. 26 illustrates a portion of an embodiment of a temple including a rack and pinion actuator showing the rotation of the wheel relative to the temple cover, according to an embodiment.

[0090] FIG. 27a illustrates a side view of screw actuator assembly 2700 with vertical compression of reservoir 2740. Slider bar 2710 works in a similar way to the slider bars

of previous embodiments. However, instead of a rack and pinion or other arrangement, screw actuator assembly 2700 provides for a worm gear arrangement between screw 2720 and slider bar 2710. When screw 2720 is rotated by rotation of dial 2730 by a user, slider bar 2710 moves to compress reservoir 2740 against temple chassis ceiling 2750 of temple chassis 2760. FIG. 27b illustrates a side view of the screw actuator assembly of FIG. 27a when compressed.

[0091] FIG. 28a illustrates a side view of an embodiment of rotation actuator assembly 2800 with a pulley-type track 2810 with vertical compression of reservoir 2860. Slider bar 2820 works in a similar way to the slider bars of previous embodiments, except it is adhered to track 2810. When wheel 2830 is rotated, it moves track 2810 around pulleys 2840 and 2850. When track 2810 moves around pulleys 2840 and 2850, slider bar 2820 moves to compress reservoir 2860 against temple chassis ceiling 2880 of temple chassis 2870. In an embodiment, as shown in FIG. 28a, slider bar 2820 is configured to bend around pulley 2850. FIG. 28b is a view of the screw actuator assembly along line A of FIG. 28a.

[0092] FIG. 29a illustrates a side view of an embodiment of slide and translate actuator 2900 with horizontal compression of its reservoir (not shown). When slider button 2910 is translated along temple arm 2920, the slider bar (not shown) moves to compress the reservoir against the temple chassis. FIG. 29b is a sectional view of the actuator assembly along an axis of temple arm 2920. Specifically, FIG. 29b is a sectional view of the slider compressing the reservoir as it translates along the axis of the temple arm.

[0093] Although various embodiments of the present invention have been described above, it should be understood that they have been presented by way of example only, and not limitation. It will be apparent to persons skilled in the relevant art that various changes in form and detail can be made therein without departing from the spirit and scope of the invention. Thus, the breadth and scope of the present invention should not be limited by any of the above-described exemplary embodiments, but should be defined only in accordance with the following claims and their equivalents.

[0094] Further, the purpose of the foregoing Abstract is to enable the U.S. Patent and Trademark Office and the public generally, and especially the scientists, engineers and practitioners in the art who are not familiar with patent or legal terms or phraseology, to determine quickly from a cursory inspection the nature and essence of the technical

disclosure of the application. The Abstract is not intended to be limiting as to the scope of the present invention in any way.

We claim:

1. An endovascular valve device for reducing reflux of an infusate having an embolic agent in a vessel during a therapy procedure, comprising:

a) a delivery catheter having a distal end, an outer diameter, and a lumen defining an inner diameter; and

b) a valve in combination with said delivery catheter, said valve including,

i) a plurality of elongate first filaments in a braid, each of said first filaments having a diameter of 0.025 mm to 0.127 mm, said first filaments having a proximal end, a distal end, and a length extending therebetween,

said proximal ends secured relative to each other such that a central opening is provided between said secured proximal ends, said first filaments along said lengths distal of said proximal ends not bonded to each other such that said first filaments are movable relative to each other,

said distal ends of said first filaments fully collapsible relative to each other into an undeployed state, and expandable from said undeployed state into a radially-expanded deployed state by a spring bias of said first filaments,

said valve in said deployed state having an opening in fluid communication with said lumen of said delivery catheter for delivery of the infusate from said delivery catheter to the vessel,

wherein in said deployed state said first filaments cross one another at an angle of 100° to 150°, and said first filaments have a Young's modulus of elasticity greater than 100 MPa; and

ii) a filter comprising a polymeric coating on said braided first filaments between said proximal and distal ends of said first filaments, said filter defining a pore size not exceeding 500µm,

wherein said valve expands from said undeployed state to said deployed state in less than one second in an at-rest fluid having a viscosity of 3.2 cP, and

wherein once said valve is in said deployed state in the vessel, said valve is dynamically movable between an expanded valve-open configuration and a collapsed valve-closed configuration depending on a local fluid pressure about said valve,

when the fluid pressure is higher on a proximal side of said valve, said valve is in said valve-closed configuration in which said distal end of said valve assumes a first diameter smaller than the diameter of the vessel such that fluid flow about the said valve and said

filter is permitted, and

when said fluid pressure is higher on a distal side of said valve, said valve is in said valve-open configuration in which said distal end of said valve assumes a second diameter relatively larger than said first diameter, and in which said valve contacts the vessel wall and said pore size of said filter renders said filter impermeable to the embolic agent of the infusate such that the valve is thereby adapted to reduce reflux, and
wherein said coating of said filter onto said first filaments of said valve constrains said filter to change shape and move with said valve between said valve-open and valve-closed configurations as fluid pressure conditions about said valve change.

2. An endovascular valve device according to claim 1, wherein:

said valve automatically expands when either

- (i) a biological fluid flows against said valve in a distal to proximal direction,
- (ii) the biological fluid is at a static flow condition, or
- (iii) there is a fluid pressure on a proximal side of said valve which is greater than a fluid pressure on a distal side of said valve thereby creating a difference in fluid pressure, said difference in fluid pressure creating a net fluid pressure on said proximal side of said valve which is less than said fluid pressure on said distal side of said valve and which is insufficient to overcome said radial force of expansion.

3. An endovascular valve device according to claim 2, wherein:

said valve is permeable to the biological fluid in the vessel when said valve assumes said second diameter.

4. An endovascular valve device according to claim 1, wherein:

said valve automatically collapses into said valve-closed configuration during systole and automatically expands into said valve-open configuration during diastole.

5. An endovascular valve device according to claim 1, wherein:

said polymeric coating comprises polymeric second filaments electrostatically deposited or spun onto said braided first filaments.

6. An endovascular valve device according to claim 1, wherein:

said first filaments are comprised of a material chosen from polyethylene terephthalate (PET), polyethylene-naphthalate (PEN), liquid crystal polymer, stainless steel, Nitinol,

fluorinated polymers, nylon, polyamide, platinum or platinum-iridium.

7. An endovascular valve device according to claim 1, wherein:

said first filaments form a substantially frustoconical shape when said valve is in said deployed state.

8. An endovascular valve device according to claim 1, wherein:

said valve in said undeployed state has a diameter smaller than or approximately equal to said inner diameter of said lumen of said delivery catheter, and in said deployed state has a diameter substantially larger than said outer diameter of said delivery catheter.

9. An endovascular valve device according to claim 8, further comprising:

a flush valve in the delivery wall of the catheter proximal the valve, the flush valve is a normally closed position and openable upon actuation or meeting a preset condition.

10. An endovascular valve device according to claim 1, further comprising:

a second catheter extending over said delivery catheter, wherein in said undeployed state said second catheter also extends over said valve and in said deployed state said valve extends distal of said second catheter.

11. An endovascular valve device according to claim 1, further comprising:

a control member having a distal end, said valve coupled to said distal end of said control member.

12. An endovascular valve device according to claim 11, wherein:

said valve comprises a tubular sleeve.

13. An endovascular valve device according to claim 11, further comprising:

a self-expanding loop, wherein a proximal end of said valve is coupled to said self-expanding loop, said valve having an open distal end.

14. An endovascular valve device according to claim 1, further comprising:

a self-expanding collar, wherein a proximal end of said valve is coupled to said self-expanding collar.

15. An endovascular valve device according to claim 1, wherein:
said valve comprises a plurality of flaps.

16. An endovascular valve device according to claim 1, further comprising:
a deployment control member controllable from said proximal end of said delivery catheter,
said control member adapted to move said valve from said undeployed state to said deployed state, wherein in said undeployed state said valve has a diameter smaller than or approximately equal to said inner diameter of said lumen of said delivery catheter, and in said deployed state said valve has a diameter substantially larger than said outer diameter of said delivery catheter.

17. An endovascular valve device according to claim 16, wherein:
said distal end of said delivery catheter includes a valve seat, said valve has mating structure engageable relative to said valve seat, and when said valve is in said deployed state, said mating structure of said valve is engaged relative to said valve seat to lock said valve at said distal end of said delivery catheter.

18. An endovascular valve device according to claim 17, wherein:
said deployment control member is retractable from said delivery catheter while said valve is locked at said distal end of said valve seat.

19. An endovascular valve device according to claim 17, wherein:
said deployment control member is a wire advanceable through said delivery catheter, said wire in contact with a portion of said valve to distally advance said valve through said lumen and to said valve seat.

20. An endovascular valve device according to claim 17, wherein:
said deployment control member is a wire coupled to said valve when said valve is locked at said distal end of said valve seat.

21. An endovascular valve device according to claim 17, further comprising:
a retraction element attached to said valve and extending through said length of said delivery catheter, said retraction element capable of applying a sufficient tensile force to said valve unlock said valve from said valve seat.

22. An endovascular valve device according to claim 21, wherein:
said deployment control member is retractable from said delivery catheter while said valve is locked at said distal end of said valve seat, and
said retraction element extends within said delivery catheter and is coupled to said valve when said deployment control member is removed from said delivery catheter.

23. An endovascular valve device according to claim 22, wherein:
said retraction element is one or more wires.

24. An endovascular valve device according to claim 22, wherein:
said retraction element includes a braid of wires.

25. An endovascular valve device according to claim 24, wherein:
said braid of wires is provided with a polymer coating.

26. An endovascular valve device according to claim 17, wherein:
said valve seat includes an inner circumferential groove provided at said distal end of said delivery catheter, and said mating structure includes an element that expands into said groove when longitudinally aligned with said groove.

27. An endovascular valve device according to claim 26, wherein:
said valve seat comprises a plurality of longitudinally displaced grooves.

28. An endovascular valve device according to claim 26, wherein: said mating structure includes an expandable flange.

29. An endovascular valve device according to claim 28, wherein:
said flange is circumferentially uninterrupted.

30. An endovascular valve device according to claim 28, wherein:
said flange is comprised of a plurality of discrete elements radially displaced about a periphery of a proximal portion of said valve.

31. An endovascular valve device according to claim 28, wherein:
said flange has a proximal end and a distal end, and said proximal end has a reduced diameter

relative to said distal end.

32. An endovascular valve device according to claim 16, further comprising:
an introducer surrounding said valve and said deployment control member, said introducer having a distal end with a diameter smaller than said inner diameter of said lumen of said delivery catheter,
said introducer constraining said diameter of said valve for introduction into said delivery catheter.

33. An endovascular valve device according to claim 16, wherein:
said deployment control member is an inner catheter extending through said delivery catheter and said valve is mounted on said inner catheter, wherein said delivery catheter and said inner catheter are axially displaceable relative to each other.

34. An endovascular valve device according to claim 1, wherein:
said valve has a radial force of expansion of less than 40 mN.

35. An endovascular device according to claim 8, wherein:
said valve is longitudinally fixed to said distal end of said first catheter.

36. An endovascular device according to claim 35, further comprising:
a second catheter extending over the delivery catheter, wherein in said undeployed state said second catheter also extends over said valve and in said deployed state said valve extends distal of said second catheter.

37. An endovascular valve device according to claim 1, wherein:
said polymeric coating comprises polymeric second filaments electrostatically deposited or spun onto said braided first filaments.

38. An endovascular valve device for reducing reflux of an infusate in a vessel during a procedure, the device comprising:

- a) an elongated delivery catheter having a proximal end and a distal end, a lumen defining an inner diameter, and an outer diameter, wherein the infusate can be delivered through said lumen;
- b) a substantially frustoconical valve longitudinally fixed at said distal end of said delivery

catheter, said valve having a housed state with a first smaller diameter and a radially-expanded deployed state with a second larger diameter, said second larger diameter being substantially larger than said outer diameter and capable of extending across a vessel through which said device is used, said valve comprising,

- i) a plurality of elongate first filaments in a braid, each of said first filaments having a diameter of 0.025 mm to 0.127 mm, said first filaments having a proximal end, distal end, and a length extending therebetween,

said proximal ends secured relative to each other, said first filaments along said lengths distal of said proximal ends not bonded to each other such that said first filaments are movable relative to each other,

said distal ends of said first filaments fully collapsible relative to each other into an undeployed state, and expandable from said undeployed state into a radially expanded deployed state by a spring bias of said first filaments,

wherein in said deployed state said first filaments cross one another at an angle of 100° to 150°, and

- ii) a filter comprising a polymeric coating on said braided first filaments between said proximal and distal ends of said first filaments, said filter defining a pore size not exceeding 500µm,

wherein once said valve is in said deployed state in the vessel, said valve is dynamically movable between an expanded valve-open configuration and a collapsed valve-closed configuration depending on a local fluid pressure about said valve,

when the fluid pressure is higher on a proximal side of said valve, said valve is in said valve-closed configuration in which said distal end of said valve assumes a first diameter smaller than the diameter of the vessel such that fluid flow about the said valve and said filter is permitted, and

when said fluid pressure is higher on a distal side of said valve, said valve is in said valve-open configuration in which said distal end of said valve assumes a second diameter relatively larger than said first diameter, and in which said valve contacts the vessel wall and said pore size of said filter renders said filter impermeable to the infusate such that the valve is thereby adapted to reduce reflux of the infusate, and

wherein said coating of said filter onto said first filament causes both of said filter and said first filaments to change shape and move together when said valve moves between said valve-open and valve-closed configurations as the pressure conditions about said valve change; and

- c) a control element movable relative to said delivery catheter for deploying said valve

from said housed state to said deployed state, and, said valve in said deployed state having an opening through which infusate can be delivered along a pathway extending through said delivery catheter and into the vessel, said valve in said deployed state automatically allowing biological fluid in the vessel to flow in a proximal to distal direction relative to the valve and preventing reflux of the infusate in the distal to proximal direction.

39. An endovascular device according to claim 38, wherein:
said valve has a radial force of expansion of less than 40 mN.

40. An endovascular valve device according to claim 38, wherein:
said polymeric coating comprises polymeric second filaments electrostatically deposited or spun onto said braided first filaments.

41. An endovascular valve device according to claim 38, wherein:
said first filaments have a Young's modulus of elasticity greater than 100 MPa, and said valve expands from said undeployed state to said deployed state in less than one second in an at-rest fluid having a viscosity of 3.2 cP.

42. An endovascular device for reducing reflux of an infusate in a vessel during a procedure, the device comprising:

- a) an elongated delivery catheter having a proximal end and a distal end, a lumen defining an inner diameter, and an outer diameter, wherein the infusate can be delivered through said lumen to the vessel;
- b) a valve seat provided at said distal end of said delivery catheter; and
- c) a valve distally displaceable through said delivery catheter to said valve seat, said valve having:
 - i) a plurality of elongate first filaments in a braid, each of said first filaments having a diameter of 0.025 mm to 0.127 mm, said first filaments having a proximal end, distal end, and a length extending therebetween,
 said proximal ends secured relative to each other, said first filaments along said lengths distal of said proximal ends not bonded to each other such that said first filaments are movable relative to each other,

said valve fully collapsible into an undeployed state, and expandable from said undeployed state into a radially-expanded deployed state by a spring bias of said first filaments,

wherein in said deployed state said first filaments cross one another at an angle of 100° to

150°, and said first filaments have a Young's modulus of elasticity greater than 100 MPa:

- ii) a filter comprising a polymeric coating on said braided first filaments between said proximal and distal ends of said first filaments, said filter defining a pore size not exceeding 500 μm , and
- iii) mating structure that is engaged with said valve seat when said valve is advanced to said valve seat to thereby lock said valve relative to said valve seat, wherein said valve in said undeployed state has a diameter smaller than or approximately equal to an inner diameter of said catheter, and in said deployed state has a diameter substantially larger than an outer diameter of said catheter, and said valve in said deployed state having an opening in fluid communication with said lumen for delivery of the infusate from said delivery catheter to the vessel,

wherein said valve expands from said undeployed state to said deployed state in less than one second in an at-rest fluid having a viscosity of 3.2 cP, and

wherein once said valve is in said deployed state in the vessel, said valve is dynamically movable between an expanded valve-open configuration and a collapsed valve-closed configuration depending on a local fluid pressure about said valve,

when the fluid pressure is higher on a proximal side of said valve, said valve is in said valve-closed configuration in which said distal end of said valve assumes a first diameter smaller than the diameter of the vessel such that fluid flow about the said valve and said filter is permitted, and

when said fluid pressure is higher on a distal side of said valve, said valve is in said valve-open configuration in which said distal end of said valve assumes a second diameter relatively larger than said first diameter, and in which said valve contacts the vessel wall and said pore size of said filter renders said filter impermeable to the infusate such that the valve is thereby adapted to reduce reflux of the infusate, and

wherein said coating of said filter onto said first filament causes both of said filter and said first filaments to change shape and move together when said valve moves between said valve-open and valve-closed configurations as the pressure conditions about said valve change.

43. A device according to claim 42, wherein:

said valve seat is located at said distal end of said delivery catheter.

44. A device according to claim 42, wherein:

said valve seat is provided within said lumen of said delivery catheter.

45. A device according to claim 42, wherein:

said valve seat includes a circumferential groove provided along an inner surface of said lumen of said delivery catheter, and said mating structure comprises at least one element which expands into said groove.

46. A device according to claim 42, further comprising:

a deployment element controllable from said proximal end of said delivery catheter, said deployment element adapted to distally advance said valve from said proximal end to said distal end of the delivery catheter.

47. A device according to claim 46, wherein:

said deployment element is a push wire advanceable through said delivery catheter, said push wire abutting a portion of said valve to distally advance said valve through said delivery catheter to said valve seat.

48. A device according to claim 46, further comprising:

a retraction element coupled to said valve, said retraction element controllable from said proximal end of said delivery catheter and structured to apply a tensile force to said valve to hold said valve relative to said valve seat.

49. A device according to claim 46, further comprising:

a retraction element coupled to said valve, said retraction element controllable from said proximal end of said delivery catheter and structured to apply a tensile force to said valve to release said valve from said valve seat and draw said valve into said delivery catheter.

50. A device according to claim 46, further comprising:

a retraction element coupled to said valve and discrete from said deployment element, said retraction element controllable from said proximal end of said delivery catheter to applying a tensile force to sufficient to release said valve from said valve seat and draw said valve into said delivery catheter.

51. An endovascular device according to claim 42, wherein:

said valve has a radial force of expansion of less than 40 mN.

52. An endovascular valve device according to claim 42, wherein:

said polymeric coating comprises polymeric second filaments electrostatically deposited or spun onto said braided first filaments.