(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) **World Intellectual Property Organization**
International Bureau

(43) **International Publication Date**
23 July 2020 (23.07.2020)

WIPO | PCT

(10) **International Publication Number**
WO 2020/150663 A1

(51) **International Patent Classification:**
A61F 9/007 (2006.01) *A61L 31/14* (2006.01)
A61M 27/00 (2006.01)

(21) **International Application Number:**
PCT/US2020/014186

(22) **International Filing Date:**
17 January 2020 (17.01.2020)

(25) **Filing Language:** English

(26) **Publication Language:** English

(30) **Priority Data:**
62/794,430 18 January 2019 (18.01.2019) US

(71) **Applicant: SHIFAMED HOLDINGS, LLC** [US/US]; 590 Division Street, Campbell, CA 95008 (US).

(72) **Inventors: ARGENTO, Claudio**; 590 Division Street, Campbell, CA 95008 (US). **MIXTER, Colin**; 590 Division Street, Campbell, CA 95008 (US). **BACKUS, Andrew**; 590 Division Street, Campbell, CA 95008 (US).

(74) **Agent: GOBER, Jacob, D.** et al.; Perkins Coie LLP, P.O. Box 1247, Seattle, WA 98111-1247 (US).

(81) **Designated States** *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS, ZA, ZM, ZW.

(84) **Designated States** *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

(54) **Title:** ADJUSTABLE FLOW GLAUCOMA SHUNTS AND METHODS FOR MAKING AND USING SAME

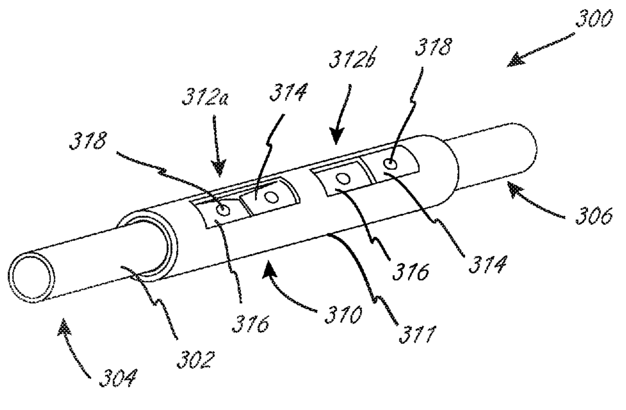


Fig. 3A

(57) **Abstract:** Adjustable flow glaucoma shunts are disclosed herein. In one embodiment, for example, a variable flow shunt for treatment of glaucoma in a human patient includes an elongated outflow tube having (a) a proximal inflow portion configured for placement within an anterior chamber in a region outside of an optical field of view of an eye of the patient, and (b) a distal outflow portion at a different location of the eye. The variable flow shunt further includes a flow control mechanism positioned along the outflow tube between the inflow portion and the outflow portion. The flow control mechanism comprises one or more control elements transformable between an open position that allows fluid to flow through the outflow tube and resistance positions that partially obstruct or attenuate fluid flow through the outflow tube. During operation, the control element(s) are movable between positions in response to non-invasive energy.

WO 2020/150663 A1

[Continued on next page]

Published:

- — *with international search report (Art. 21(3))*
- — *before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments (Rule 48.2(h))*

ADJUSTABLE FLOW GLAUCOMA SHUNTS AND METHODS FOR MAKING AND USING SAME

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims the benefit of U.S. Patent Application No. 62/794,430, filed January 18, 2019, and titled "ADJUSTABLE FLOW GLAUCOMA SHUNTS AND METHODS FOR MAKING AND USING SAME," which is incorporated herein by reference in its entirety.

TECHNICAL FIELD

[0002] The present technology relates to adjustable flow glaucoma shunts and methods for making and using such devices.

BACKGROUND

[0003] Glaucoma (e.g., ocular hypertension) is a disease associated with an increase in pressure within the eye resultant from an increase in production of aqueous humor (aqueous) within the eye and/or a decrease in the rate of outflow of aqueous from within the eye into the blood stream. Aqueous is produced in the ciliary body at the boundary of the posterior and anterior chambers of the eye. It flows into the anterior chamber and eventually into the capillary bed in the sclera of the eye. Glaucoma typically results from a failure in mechanisms that transport aqueous out of the eye and into the blood stream.

BRIEF DESCRIPTION OF THE DRAWINGS

[0004] Many aspects of the present technology can be better understood with reference to the following drawings. The components in the drawings are not necessarily drawn to scale. Instead, emphasis is placed on illustrating clearly the principles of the present technology. Furthermore, components can be shown as transparent in certain views for clarity of illustration only and not to indicate that the component is necessarily transparent. Components may also be shown schematically.

[0005] FIGS. 1A–1C illustrate glaucoma plate shunts configured to provide constant resistance to flow.

[0006] FIG. 2A is simplified front view of an eye E with an implanted shunt, and FIG. 2B is an isometric view of the eye capsule of FIG. 2A.

[0007] FIGS. 3A and 3B illustrate an adjustable flow glaucoma shunt configured in accordance with an embodiment of the present technology.

[0008] FIGS. 4A and 4B illustrate an adjustable flow glaucoma shunt configured in accordance with another embodiment of the present technology.

[0009] FIGS. 5A–5C illustrate a variable fluid resistor device configured in accordance with an embodiment of the present technology.

[0010] FIGS. 6A–6C illustrate an adjustable flow glaucoma shunt configured in accordance with still another embodiment of the present technology.

DETAILED DESCRIPTION

[0011] The present technology is directed to adjustable flow glaucoma shunts and methods for making and using such devices. In many of the embodiments disclosed herein, the adjustable flow glaucoma shunts comprise an adjustable fluid resistor ("resistor" within the context of this document refers to a fluid resistor), actuator, and/or actuation mechanism. Additionally, in certain embodiments, the shunts may also include an adjustable opening pressure control mechanism. These mechanisms can be selectively adjusted or modulated to increase or decrease the outflow resistance and/or opening pressure of the shunt in response to changes in any (or any combination of) intraocular pressure (IOP), aqueous production rate, native aqueous outflow resistance, and/or native aqueous outflow rate.

[0012] In one embodiment, for example, a variable flow shunt for treating glaucoma in a human patient comprises an elongated outflow tube having (a) a proximal inflow portion configured for placement within an anterior chamber in a region outside of an optical field of view of an eye of the patient, and (b) a distal outflow portion at a different location of the eye. The variable flow shunt further includes a flow control mechanism positioned along the outflow tube between the inflow portion and the outflow portion. The flow control mechanism comprises one or more control elements transformable between an open position that allows fluid to flow through the outflow tube and resistance positions that partially obstruct or attenuate fluid flow through the outflow tube. During operation, the control element(s) are movable between positions in response to non-invasive energy.

[0013] In another embodiment of the present technology, a shunt for treatment of glaucoma in a human patient comprises an elongated outflow drainage tube having a proximal inflow region and a distal outflow region. The shunt also includes an inflow control assembly at the proximal inflow region, and a transition region along the outflow tube between the inflow region and the outflow region. During operation, the transition region is transformable between a first shape and a second shape different than the first shape to inhibit or attenuate fluid flow through the outflow tube.

[0014] A method for treating glaucoma in a human patient in accordance with still another embodiment of the present technology can include positioning a variable flow shunt within an eye of the patient. The shunt comprises an elongated outflow drainage tube having a proximal inflow region at a first portion of the eye and a distal outflow region at a second, different portion of the eye. The method also includes transforming a flow control assembly carried by the elongated outflow drainage tube from a first configuration to second, different configuration to selectively control flow of aqueous through the variable flow shunt. Throughout the method, the flow control assembly may be actuated via non-invasive energy.

[0015] Specific details of various embodiments of the present technology are described below with reference to FIGS. 1A–6C. Although many of the embodiments are described below with respect to adjustable flow glaucoma shunts and associated methods, other embodiments are within the scope of the present technology. Additionally, other embodiments of the present technology can have different configurations, components, and/or procedures than those described herein. For instance, shunts configured in accordance with the present technology may include additional elements and features beyond those described herein, or other embodiments may not include several of the elements and features shown and described herein.

[0016] For ease of reference, throughout this disclosure identical reference numbers are used to identify similar or analogous components or features, but the use of the same reference number does not imply that the parts should be construed to be identical. Indeed, in many examples described herein, the identically numbered parts are distinct in structure and/or function.

Implantable Shunts for Glaucoma Treatment

[0017] Glaucoma is a degenerative ocular condition characterized by an increase in pressure within the eye resultant from an increase in production of aqueous humor (aqueous) within the eye and/or a decrease in the rate of outflow of aqueous from within the eye into the blood stream. The early stages of glaucoma are typically treated with drugs (e.g., eye drops). When drug treatments no longer suffice, however, surgical approaches may be used. Surgical or minimally invasive approaches primarily attempt to increase the outflow of aqueous from the anterior chamber to the blood stream either by the creation of alternative fluid paths or the augmentation of the natural paths for aqueous outflow.

[0018] Devices used to lower outflow resistance are generally referred to as "glaucoma shunts" or "shunts." FIGS. 1A–1C, for example, illustrate several different traditional glaucoma plate shunts 100 (identified individually as 100a-c) configured to provide constant resistance to flow. The shunt 100a of FIG. 1A, for example, includes a plate 103a, a plurality of outflow ports 102a, one or more inflow ports 101, and tie-downs or engagement features 104a. The shunts 100b and 100c shown in FIGS. 1B and 1C, respectively, include several features similar to the features of shunt 100a. For example, these shunts 100b-c include plates 103b-c, outflow ports 102b-c, and tie-downs or engagement features 104b-c. The shunts 100b-c, however, include an inflow tube 105 instead of the inflow ports 101 of the shunt 100a.

[0019] FIGS. 2A and 2B illustrate a human eye E and suitable location(s) in which shunts 100a-c may be implanted within the eye. More specifically, FIG. 2A is a simplified front view of the eye E, and FIG. 2B is an isometric view of the eye capsule of FIG. 2A. Referring first to FIG. 2A, the eye E includes a number of muscles to control its movement, including a superior rectus SR, inferior rectus IR, lateral rectus LR, medial rectus MR, superior oblique SO, and inferior oblique IO. The eye E also includes an iris, pupil, and limbus.

[0020] Referring to FIGS. 2A and 2B together, shunt 100c is positioned such that inflow tube 105 is positioned in an anterior chamber of the eye, and outflow ports 102c are positioned at a different location within the eye. Depending upon the design of the device, the outflow ports 102c may be place in a number of different suitable outflow locations (e.g., between the choroid and the sclera, between the conjunctiva and the sclera). For purposes of illustration, only shunt 100c is shown implanted in the eye E. It will be appreciated, however, that shunts 100a-b may be similarly implanted within the eye E.

[0021] Outflow resistance changes over time as the outflow location goes through its healing process after surgical implantation of the device. Because the outflow resistance changes over time, in many procedures the shunt (e.g., shunts 100a-c) is modified at implantation to temporarily increase its outflow resistance. After a period of time deemed sufficient to allow for healing of the tissues and stabilization of the outflow resistance, the modification to the shunt is reversed, thereby decreasing the outflow resistance. Such modifications can be invasive, time-consuming, and expensive for patients. If such a procedure is not followed, however, the likelihood of creating hypotany and its resultant problems is high. Accordingly, the present technology provides variable flow glaucoma shunts that enable a user to remotely actuate a flow control mechanism to selectively alter the flow of fluid through the shunt. The selectively adjustable shunts may be similar in certain aspects to those described in PCT Patent Publication No. 2019/018807, titled "ADJUSTABLE FLOW GLAUCOMA SHUNTS AND METHODS FOR MAKING AND USING SAME," the disclosure of which is incorporated by reference herein in its entirety.

Selected Embodiments of Variable Flow Glaucoma Shunts

[0022] FIGS. 3A–6C illustrate a number of different embodiments for variable flow glaucoma shunt devices, along with particular components and features associated with such devices. FIG. 3A, for example, illustrates a variable flow glaucoma shunt 300 ("shunt 300") configured in accordance with an embodiment of the present technology. The shunt 300 includes an elongated drainage tube 302 (e.g., a fine bore length of thin walled tubing) having a proximal portion with an inflow portion 304 and a distal outflow portion 306 opposite the proximal portion. The inflow portion 304 of the shunt 300 is configured for placement within an anterior chamber in a region outside of the optical field of view of the eye, but within a region visible through the cornea. For purposes of illustration, the outflow portion 306 is shown relatively adjacent to the inflow portion 304. It will be appreciated, however, that the drainage tube 302 is sized and shaped to span a region between the anterior chamber and a desired outflow location within the eye of the patient (e.g., a bleb space).

[0023] The shunt 300 further includes a flow control mechanism 310 positioned along the drainage tube 302 and configured to act as a variable resistor during operation and selectively control flow of fluid through the drainage tube 302. In the illustrated embodiment, for example, the flow control mechanism 310 comprises a body portion 311 slidably positioned along the drainage tube 302. In other embodiments, however, the flow control mechanism 310 may be carried by or engaged with the drainage tube 302 in a different arrangement. The flow control mechanism 310 includes one or more control elements 312 (two are shown in the illustrated embodiment as a first control element 312a and a second control element 312b). The flow control elements 312a-b are configured to be selectively activated by non-invasive energy (e.g., a surgical laser, light, heat, etc.) and, upon activation, pivotably move into the flow path through the drainage tube 302 to inhibit/attenuate flow therethrough. In various embodiments, flow is modified in some manner (e.g. pressure and/or flow) between the activated and non-activated configurations. In various embodiments, activation inhibits and/or attenuates flow through the drainage tube. One will appreciate from the description herein that activation may refer to selecting or moving between one of a variety of positions or configurations of the flow control mechanism. Further, in various embodiments, in the unactivated configuration, the drainage tube 302 is fully open. In various embodiments, in the activated configuration, the drainage tube is fully closed, thus preventing/inhibiting fluid flow through the drainage tube 302.

[0024] FIG. 3B, for example, is a partially schematic cross-sectional side view of the shunt 300 during operation. Referring to FIGS. 3A and 3B together, the first control element 312a includes a first finger 314 and a second finger 316. The first and second fingers 314 and 316 are pivotably movable relative to each other and the drainage tube 302 to transform the flow control mechanism 310 between an open configuration and a variety of different partially closed configurations (up to a fully closed configuration). In the illustrated embodiment, the first finger 314 is positioned to partially overlap the second finger 316. In other embodiments, however, the first and second fingers 314 and 316 may have a different arrangement relative to each other.

[0025] The first and second fingers 314 and 316 also each include target indicia or marker(s) 318 ("targets 318"). One or more individual targets 318 are included on each of the first and second fingers 314 and 316 and positioned as markers/targets for non-invasive energy used to selectively activate the flow control mechanism 310. The first and second fingers 314 and 316 are composed of a shape memory material (e.g., nitinol) and adapted to pivotably move when such non-invasive energy is applied. For example, applying heat to the first finger 314 (e.g., non-invasive energy applied to target(s) 318 on the first finger 314) can induce this feature to depress or move downward, thereby pushing the corresponding second finger 316 into the flow path (as best seen in FIG. 3B). Likewise, applying heat to the second finger 316 can induce this feature to lift/pivotably move upward, thereby pushing the corresponding first finger 314 upward and back toward an initial, non-obstructive position within the flow path. The first finger 314 and/or second finger 316 can be selectively activated via the non-invasive energy to provide precise control over the flow control element 312 and the resulting fluid flow via the drainage tube 302.

[0026] In the illustrated embodiment, the shunt 300 includes two flow control elements 312a and 312b positioned adjacent each other along the drainage tube 302. In other embodiments, however, the shunt 300 may include a different number of flow control elements 312 (e.g., a single flow control element 312 or greater than two flow control elements 312). Further, the individual flow control elements 312 may have a different arrangement relative to each other along the drainage tube 302.

[0027] FIGS. 4A and 4B illustrate a shunt 400 configured in accordance with anther embodiment of the present technology. The shunt 400 includes a flow control mechanism 410 configured for use with the drainage tube 302 (other another suitable drainage tube), and configured to act as a variable resistor and selectively control flow of fluid through the tube. The shunt 400 includes several features similar to the features of the shunt 300 described above with reference to FIGS. 3A and 3B. For example, FIG. 4A is a partially exploded view of the shunt 400 showing individual components of the shunt 400, and FIG. 4B is an isometric view of the assembled flow control mechanism 410 before installation with the drainage tube 302. Referring to FIGS. 4A and 4B together, the shunt 400 includes a flow control mechanism 410 positioned along the drainage tube 302. Flow control mechanism 410 comprises a first plate 411a configured to be engaged with the drainage tube 302, and a second plate 411b configured to be operably coupled with or engaged with the first plate 411a. The flow control mechanism 410 further comprises a plurality of first flow control elements 412a carried by the first plate 411a, and a plurality of second flow control elements 412b carried by the second plate 411b. The first and second flow control elements 412a and 412b are positioned to be aligned when the first plate 411a and the second plate 411b are joined together and mated in a stacked configuration.

[0028] When engaged with the drainage tube 302, the flow control mechanism 410 is configured to function in a similar fashion to the flow control mechanism 310 described above with reference to FIGS. 3A and 3B. For example, the first flow control elements 412a each include a first finger 414 pivotably movable relative to the drainage tube 302 to transform the flow control mechanism 410 between an open configuration and a variety of different partially closed configurations (up to a fully closed configuration) in which the flow path through the drainage tube 302 is inhibited/attenuated (see, for example, the arrangement shown in FIG. 3B). The second flow control elements 412b each include a second finger 416 pivotably movable relative to the drainage tube 302 to engage the corresponding first fingers 414 and lift the first fingers 414 to transform the flow control mechanism 410 between the partially closed (or fully closed) configuration to a more open (or fully open) configuration. The first and second flow control elements 412a and 412b also each include target indicia or marker(s) 418. The targets

418 are positioned as markers/targets for non-invasive energy used to selectively activate the first and second flow control elements 412a and 412b during operation of the shunt 400.

[0029] In the illustrated embodiment, the flow control mechanism 410 of the shunt 400 includes three first flow control elements 412a and three second flow control elements 412b. In other embodiments, however, the shunt 400 may include a different number of flow control elements 412 and/or the individual flow control elements 412 may have a different arrangement relative to each other. In some embodiments, for example, the flow control elements 412 may be oriented in the opposite direction as that shown in FIGS. 4A and 4B.

[0030] FIGS. 5A–5C illustrate a variable fluid resistor shunt 500 ("shunt 500") configured in accordance with an embodiment of the present technology. Referring to FIGS. 5A and 5B together, for example, drainage tube 502 comprises a first portion 504 and a second portion 506 opposite the first portion. A manifold 520 (e.g., a variable resistor assembly) is engaged with the drainage tube 502 and positioned at or adjacent with the second portion 506. The manifold 520 comprises multiple parallel lumens 522 arrayed across the width of the manifold 520 (FIG. 5A). For example, the manifold 520 can comprise two, three, four, five, six, or more lumens 522. When implanted in an eye, the manifold 520 can reside within a desired outflow location (e.g., a bleb space) or within a desired inflow location (e.g., an anterior chamber). Accordingly, the shunt 500 can be configured such that flow goes in either direction through the shunt 500.

[0031] Each of the lumens 522 further comprises a flow control element 524. As best seen in FIG. 5B, individual flow control elements 524 are transformable between a first (e.g., open) position in which flow is not impeded and a second (e.g., closed) position in which flow through the corresponding lumen 522 is blocked or attenuated. The flow control elements 524 are all individually addressable (e.g., via non-invasive energy or other suitable mechanisms) such that flow through each of the lumens 522 can be selectively controlled. Referring to FIG. 5C, for example, flow through a majority of the lumens 522 has been attenuated or blocked via the corresponding flow control elements 524, but flow through the three lumens 522 on the leftmost portion of the manifold 520 remains open. It will be appreciated that selectively controlling flow via the manifold 520 allows for precise variable control of fluid outflow via the shunt 500. Further, in other embodiments, the manifold 520 of the shunt 500 may include a different number of lumens 522 and/or flow control elements 524, and the flow control elements 524 may have a different configuration.

[0032] In some embodiments, the lumens 522 may each have the same flow resistance. In embodiments in which the lumens 522 have the same flow resistance, opening additional lumens 522 is expected to result in a generally linear increase in the drainage rate, and blocking lumens 522 is expected to result in a generally linear decrease in the drainage rate. For example, moving from a single open lumen to two open lumens is expected to generally double the drainage rate, while moving from two open lumens to three open lumens is expected to generally increase the drainage rate by 50 percent.

[0033] In other embodiments, however, the lumens 522 may have different flow resistances. Flow resistance through the lumens 522, and thus drainage rates through the lumens 522, can be varied based on, for example, a length of the lumen and/or a diameter of the lumen. The length of the lumen is generally proportional to the flow resistance of the lumen, whereas the diameter of the lumen is generally inversely proportional to the flow resistance of the lumen. Accordingly, each individual lumen 522 may have a unique length, diameter, or length and diameter combination that gives it a certain flow resistance. Individual channels can then be selectively opened (or closed) to achieve a desired flow rate.

[0034] FIGS. 6A–6C illustrate an adjustable flow glaucoma shunt 600 ("shunt 600") configured in accordance with still another embodiment of the present technology. Referring first to FIG. 6A, for example, the shunt 600 includes an inflow control assembly 610 and an outflow drainage tube or outflow assembly 620. The inflow control assembly 610 is configured for placement within an anterior chamber in a region outside of the optical field of view of the eye, but within a region visible through the cornea. The outflow drainage tube 620 comprises tubing (e.g., a fine bore length of thin walled tubing) sized and shaped to span the region between the anterior chamber and a desired outflow location. As described in greater detail below, the inflow control assembly 610 comprises a control mechanism configured to act as a variable resistor during operation.

[0035] FIG. 6B is an enlarged view of the inflow control assembly 610 shown in operation. As best seen in FIG. 6B, the inflow control assembly 610 includes a first spring element 630a and a second spring element 630b arranged adjacent each other. In the illustrated embodiment, the first and second spring elements 630a and 630b are integrally formed from the same tube using a laser cutting process. In other embodiments, however, the first and second spring elements 630a and 630b may be separate, discrete components formed from different materials (e.g., nitinol, shape memory material, etc.). Further, it will be appreciated that the cut pattern, cut profile, and/or cut sizes within the tube may be optimized to increase/decrease flow through the spring elements 630a and 630b. The inflow control assembly 610 further includes a core element or plug feature 640 slidably received within an inner portion of the inflow control assembly 610 and selectively engaged with a selected spring element 630a or 630b.

[0036] As best seen in FIG. 6B and 6C, in operation, the first and second spring elements 630a and 630b are configured to be selectively activated by non-invasive energy and, upon activation, expand to allow flow through the corresponding spring body (i.e., the helical cuts in the tube), as well as compress the opposing spring element. The core element 640 extends approximately the length of one of the spring elements (the first spring element 630a in the illustrated arrangement) and can be positioned such that when the first spring element 630a opens, there is little or no flow path therethrough. During further operation of the shunt 600, the compressed second spring element 630b can be targeted with non-invasive energy (e.g., laser energy), which causes the second spring element 630b to expand/actuate, while causing the first spring element 630a to compress, thereby oscillating the shunt 600 and selectively controlling the flow therethrough.

[0037] In further embodiments, the inflow control assembly 610 of the shunt 600 may include one or more additional spring elements 630 positioned to be actuated to selectively control fluid flow. Further, in some embodiments the shunt 600 can include a thermal isolation element positioned between the individual springs to help further ensure that only one spring actuates at a time after delivery of non-invasive energy. The thermal isolation element(s) are an optional feature that may not be included in some embodiments.

[0038] In many of the embodiments described herein, the actuators or fluid resistors are configured to introduce features that selectively impede or attenuate fluid flow through the drainage tube during operation. In this way, the actuators/fluid resistors can incrementally or continuously change the flow resistance through the drainage tube to selectively regulate pressure/flow. The actuators and fluid resistors configured in accordance with the present technology can accordingly adjust the level of interference or compression between a number of different positions, and accommodate a multitude of variables (e.g., IOP, aqueous production rate, native aqueous outflow resistance, and/or native aqueous outflow rate) to precisely regulate flow rate through the drainage tube.

[0039] The disclosed actuators and fluid resistors can all be operated using non-invasive energy. This feature allows such devices to be implanted in the patient and then modified/adjusted over time without further invasive surgeries or procedures for the patient. Further, because the devices disclosed herein may be actuated via non-invasive energy, such devices do not require any additional power to maintain a desired orientation or position. Rather, the actuators/fluid resistors disclosed herein can maintain a desired position/orientation without power. This can significantly increase the usable lifetime of such devices and enable such devices to be effective long after the initial implantation procedure.

Examples

[0040] Several aspects of the present technology are set forth in the following examples.

1. A variable flow shunt for treatment of glaucoma in a human patient, the variable flow shunt comprising:

an elongated outflow tube having (a) a proximal inflow portion configured for placement within an anterior chamber in a region outside of an optical field of view of an eye of the patient, and (b) a distal outflow portion at a different location of the eye; and

a flow control mechanism positioned along the outflow tube between the inflow portion and the outflow portion, wherein the flow control mechanism comprises one or more control elements transformable between an open position that allows fluid to flow through the outflow tube and at least one resistance position that reduces fluid flow through the outflow tube,

wherein during operation, the one or more control elements are movable between the open position and the at least one resistance position in response to non-invasive energy.

2. The variable flow shunt of example 1 wherein the one or more control elements are transformable between a first resistance position that provides a first level of reduction of fluid flow, and a second resistance position that provides a second level of reduction of fluid flow greater than the first level of reduction.

3. The variable flow shunt of example 1 wherein the one or more control elements are transformable between a first resistance position that provides a first level of flow reduction and a plurality of second resistance positions that provide increasing levels of flow reduction.

4. The variable flow shunt of example 1 or example 2 wherein the one or more control elements are configured to partially obstruct fluid flow through the outflow tube in the at least one resistance position by changing a diameter and/or a cross-sectional shape of a flow path through the outflow tube.

5. The variable flow shunt of any one of examples 1–4 wherein the one or more control elements are movable between the open position and the at least one resistance position in response to laser energy.

6. The variable flow shunt of any one of examples 1–5 wherein the one or more control elements are configured to hold the open position or the at least one resistance position without power.

7. The variable flow shunt of example 1 wherein at least one control element comprises:

a first finger pivotably movable between a first, open position in which the first finger is out of a flow path through the outflow tube and one or more second resistance positions in which the first finger impedes fluid flow along the flow path; and

a second finger engaged with the first finger and configured to pivotably move the first finger from the one or more one or more second resistance positions toward the first open position,

wherein the first and second fingers are pivotably movable in response to the non-invasive energy.

8. A shunt for treatment of glaucoma in a human patient, the shunt comprising:

an elongated outflow drainage tube having a proximal inflow region and a distal outflow region;

an inflow control assembly at the proximal inflow region; and

a transition region along the outflow tube between the inflow region and the outflow region, wherein, during operation, the transition region is transformable between a first shape and a second shape different than the first shape to inhibit and/or attenuate fluid flow through the outflow tube.

9. The shunt of example 8 wherein the transition region is configured to transform between the first shape and the second shape upon application of non-invasive energy to one or more selected areas of the transition region.

10. The shunt of example 9 wherein the non-invasive energy is laser energy.

11. A method for treating glaucoma in a human patient, the method comprising:

positioning a variable flow shunt within an eye of the patient, wherein the shunt comprises an elongated outflow drainage tube having a proximal inflow region at a first portion of the eye and a distal outflow region at a second, different portion of the eye; and

transforming a flow control assembly carried by the elongated outflow drainage tube from a first configuration to a second, different configuration to selectively control flow of aqueous through the variable flow shunt,

wherein the flow control assembly is actuated via non-invasive energy.

12. The method of example 11 wherein transforming the flow control assembly carried by the elongated outflow drainage tube comprises actuating the flow control assembly, via the non-invasive energy, to pivotably move a control element of the control assembly into a flow path of the drainage tube such that flow along the flow path is attenuated.

13. The method of example 12, further comprising actuating the flow control assembly, via the non-invasive energy, to pivotably move the control element out of the flow path of the drainage tube such that flow along the flow path is returned to a non-attenuated state.

14. An adjustable flow shunt for treating glaucoma in a human patient, the shunt comprising:

an elongated outflow drainage tube having a proximal inflow region and a distal outflow region; and

an inflow control assembly at the proximal inflow region, wherein the inflow control assembly comprises—

a first spring element;

a second spring element positioned adjacent to the first element; and a core element sized and shaped to be slidably received within one of the first or second spring elements,

wherein the first spring element is configured to be selectively activated by non-invasive energy and, upon activation, expand such that (a) the second spring element positioned adjacent the first spring element is compressed, and (b) the expansion selectively allows fluid flow through the expanded first spring element.

15. The adjustable flow shunt of example 14 wherein the inflow control assembly is configured for placement within an anterior chamber in a region outside of the optical field of view of the eye.

16. The adjustable flow shunt of example 14 or example 15 wherein the spring element is configured to be activated via laser energy.

17. The adjustable flow shunt of any one of examples 14–16 wherein the spring element is composed of a shape memory material.

18. The adjustable flow shunt of any one of examples 14–16 wherein the spring element is composed of nitinol.

19. A variable fluid resistor shunt for treatment of glaucoma, the variable fluid resistor shunt comprising:

an elongated drainage tube having a first portion configured to be in fluid communication with a fluid chamber in an eye of a human patient and a second portion opposite the first portion;

a variable resistor assembly configured to selectively control flow of fluid through the drainage tube, wherein the variable resistor assembly comprises—

a base portion;

multiple fluid lumens arranged in an array across the base portion in fluid communication with the drainage tube; and

a plurality of flow control elements, wherein each fluid lumen includes a flow control element positioned to selectively control fluid flow along the corresponding fluid lumen;

wherein, during operation, the individual flow control elements are configured to be selectively targeted and actuated via non-invasive energy to change each flow control element between a first open position in which fluid can flow through the corresponding fluid lumen and a second at least partially closed position in which fluid flow through the corresponding fluid lumen is reduced.

20. The variable fluid resistor shunt of example 19 wherein at least two of the multiple fluid lumens have a different flow resistance when the corresponding flow control element is in the first open position.

21. The variable fluid resistor shunt of example 19 or example 20 wherein the multiple fluid lumens include a first lumen and a second lumen, and wherein the first lumen has a first diameter and the second lumen has a second diameter greater than the first diameter.

22. The variable fluid resistor shunt of any of examples 19–21 wherein the multiple fluid lumens include a first lumen and a second lumen, and wherein the first lumen has a first length and the second lumen has a second length greater than the first length.

23. The variable fluid resistor shunt of example 19 wherein each of the multiple fluid lumens have the same flow resistance when the corresponding flow control element is in the first open position.

Conclusion

[0041] The above detailed description of embodiments of the technology are not intended to be exhaustive or to limit the technology to the precise form disclosed above. Although specific embodiments of, and examples for, the technology are described above for illustrative purposes, various equivalent modifications are possible within the scope of the technology as those skilled in the relevant art will recognize. For example, any of the features of the variable flow shunts described herein may be combined with any of the features of the other variable flow shunts described herein and vice versa. Moreover, although steps are presented in a given order, alternative embodiments may perform steps in a different order. The various embodiments described herein may also be combined to provide further embodiments.

[0042] From the foregoing, it will be appreciated that specific embodiments of the technology have been described herein for purposes of illustration, but well-known structures and functions associated with variable flow shunts have not been shown or described in detail to avoid unnecessarily obscuring the description of the embodiments of the technology. Where the context permits, singular or plural terms may also include the plural or singular term, respectively.

[0043] Moreover, unless the word "or" is expressly limited to mean only a single item exclusive from the other items in reference to a list of two or more items, then the use of "or" in such a list is to be interpreted as including (a) any single item in the list, (b) all of the items in the list, or (c) any combination of the items in the list. Additionally, the term "comprising" is used throughout to mean including at least the recited feature(s) such that any greater number of the same feature and/or additional types of other features are not precluded. It will also be appreciated that specific embodiments have been described herein for purposes of illustration, but that various modifications may be made without deviating from the technology. Further, while advantages associated with some embodiments of the technology have been described in the context of those embodiments, other embodiments may also exhibit such advantages, and not all embodiments need necessarily exhibit such advantages to fall within the scope of the technology. Accordingly, the disclosure and associated technology can encompass other embodiments not expressly shown or described herein.

CLAIMS

I/We claim:

1. A variable flow shunt for treatment of glaucoma in a human patient, the variable flow shunt comprising:

an elongated outflow tube having (a) a proximal inflow portion configured for placement within an anterior chamber in a region outside of an optical field of view of an eye of the patient, and (b) a distal outflow portion at a different location of the eye; and

a flow control mechanism positioned along the outflow tube between the inflow portion and the outflow portion, wherein the flow control mechanism comprises one or more control elements transformable between an open position that allows fluid to flow through the outflow tube and at least one resistance position that reduces fluid flow through the outflow tube,

wherein, during operation, the one or more control elements are movable between the open position and the at least one resistance position in response to non-invasive energy.

2. The variable flow shunt of claim 1 wherein the one or more control elements are transformable between a first resistance position that provides a first level of reduction of fluid flow, and a second resistance position that provides a second level of reduction of fluid flow greater than the first level of reduction.

3. The variable flow shunt of claim 1 wherein the one or more control elements are transformable between a first resistance position that provides a first level of flow reduction and a plurality of second resistance positions that provide increasing levels of flow reduction.

4. The variable flow shunt of claim 1 wherein the one or more control elements are configured to partially obstruct fluid flow through the outflow tube in the at least one resistance position by changing a diameter and/or a cross-sectional shape of a flow path through the outflow tube.

5. The variable flow shunt of claim 1 wherein the one or more control elements are movable between the open position and the at least one resistance position in response to laser energy.

6. The variable flow shunt of claim 1 wherein the one or more control elements are configured to hold the open position or the at least one resistance position without power.

7. The variable flow shunt of claim 1 at least one control element comprises:

a first finger pivotably movable between a first, open position in which the first finger is out of a flow path through the outflow tube and one or more second resistance positions in which the first finger impedes fluid flow along the flow path; and

a second finger engaged with the first finger and configured to pivotably move the first finger from the one or more one or more second resistance positions toward the first open position,

wherein the first and second fingers are pivotably movable in response to the non-invasive energy.

8. A variable fluid resistor shunt for treatment of glaucoma, the variable fluid resistor shunt comprising:

an elongated drainage tube having a first portion configured to be in fluid communication with a fluid chamber in an eye of a human patient and a second portion opposite the first portion;

a variable resistor assembly configured to selectively control flow of fluid through the drainage tube, wherein the variable resistor assembly comprises—

a base portion;

multiple fluid lumens arranged in an array across the base portion and in fluid communication with the drainage tube; and

a plurality of flow control elements, wherein each fluid lumen includes a flow control element positioned to selectively control fluid flow along the corresponding fluid lumen,

wherein, during operation, the individual flow control elements are configured to be selectively targeted and actuated via non-invasive energy to change each flow control element between a first open position in which fluid can flow through the corresponding fluid lumen and a second at least partially closed position in which fluid flow through the corresponding fluid lumen is reduced.

9. The variable fluid resistor shunt of claim 8 wherein at least two of the multiple fluid lumens have a different flow resistance when the corresponding flow control elements are in the first open position.

10. The variable fluid resistor shunt of claim 8 wherein the multiple fluid lumens include a first lumen and a second lumen, and wherein the first lumen has a first diameter, and wherein the second lumen has a second diameter greater than the first diameter.

11. The variable fluid resistor shunt of claim 8 wherein the multiple fluid lumens include a first lumen and a second lumen, and wherein the first lumen has a first length, and wherein the second lumen has a second length greater than the first length.

12. The variable fluid resistor shunt of claim 8 wherein each of the multiple fluid lumens have the same flow resistance when the corresponding flow control element is in the first open position.

13. A shunt for treatment of glaucoma in a human patient, the shunt comprising:

an elongated outflow drainage tube having a proximal inflow region and a distal outflow region;

an inflow control assembly at the proximal inflow region; and

a transition region along the outflow tube between the inflow region and the outflow region, wherein, during operation, the transition region is transformable between a first shape and a second shape different than the first shape to inhibit and/or attenuate fluid flow through the outflow tube.

14. The shunt of claim 13 wherein the transition region is configured to transform between the first shape and the second shape upon application of non-invasive energy to one or more selected areas of the transition region.

15. The shunt of claim 14 wherein the non-invasive energy is laser energy.

16. A method for treating glaucoma in a human patient, the method comprising:

positioning a variable flow shunt within an eye of the patient, wherein the shunt comprises an elongated outflow drainage tube having a proximal inflow region at a first portion of the eye and a distal outflow region at a second, different portion of the eye; and

transforming a flow control assembly carried by the elongated outflow drainage tube from a first configuration to a second, different configuration to selectively control flow of aqueous through the variable flow shunt,

wherein the flow control assembly is actuated via non-invasive energy.

17. The method of claim 16 wherein transforming the flow control assembly carried by the elongated outflow drainage tube comprises actuating the flow control assembly, via the non-invasive energy, to pivotably move a control element of the control assembly into a flow path of the drainage tube such that flow along the flow path is attenuated.

18. The method of claim 17, further comprising actuating the flow control assembly, via the non-invasive energy, to pivotably move the control element out of the flow path of the drainage tube such that flow along the flow path is returned to a non-attenuated state.

19. An adjustable flow shunt for treating glaucoma in a human patient, the shunt comprising:

an elongated outflow drainage tube having a proximal inflow region and a distal outflow region; and

an inflow control assembly at the proximal inflow region, wherein the inflow control assembly comprises—

a first spring element;

a second spring element positioned adjacent to the first element; and

a core element sized and shaped to be slidably received within one of the first or second spring elements,

wherein the first spring element is configured to be selectively activated by non-invasive energy and, upon activation, expand such that (a) the second spring element positioned adjacent the first spring element is compressed, and (b) the expansion selectively allows fluid flow through the expanded first spring element.

20. The adjustable flow shunt of claim 19 wherein the inflow control assembly is configured for placement within an anterior chamber in a region outside of the optical field of view of the eye.

21. The adjustable flow shunt of claim 19 wherein the spring element is configured to be activated via laser energy.

22. The adjustable flow shunt of claim 19 wherein the spring element is composed of a shape memory material.

23. The adjustable flow shunt of claim 19 wherein the spring element is composed of nitinol.

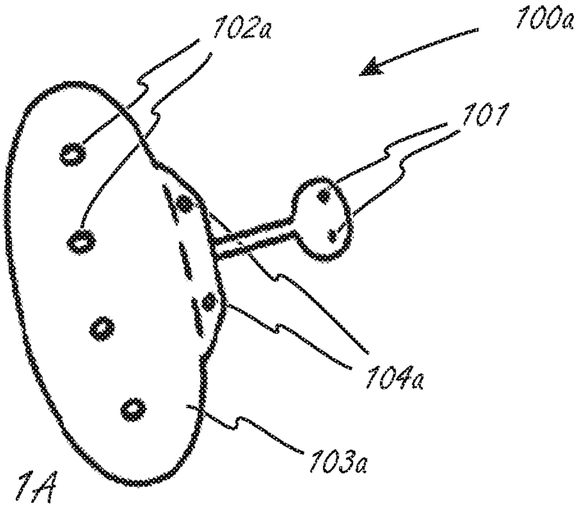


Fig. 1A

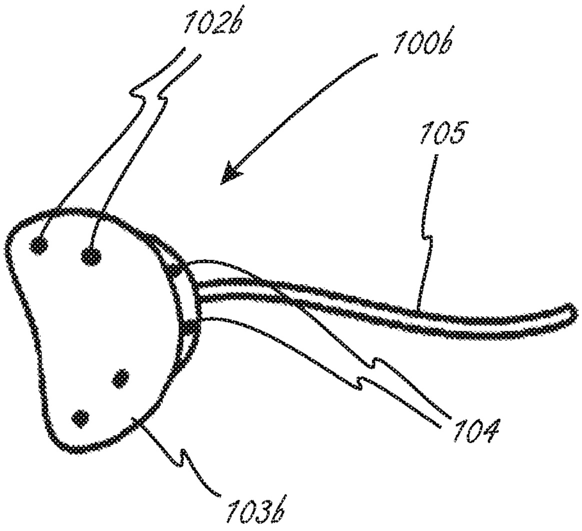
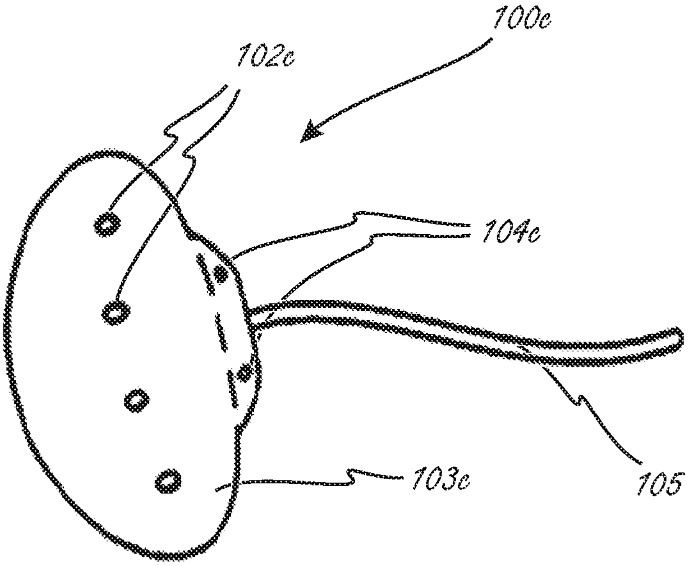


Fig. 1B

Fig. 1C



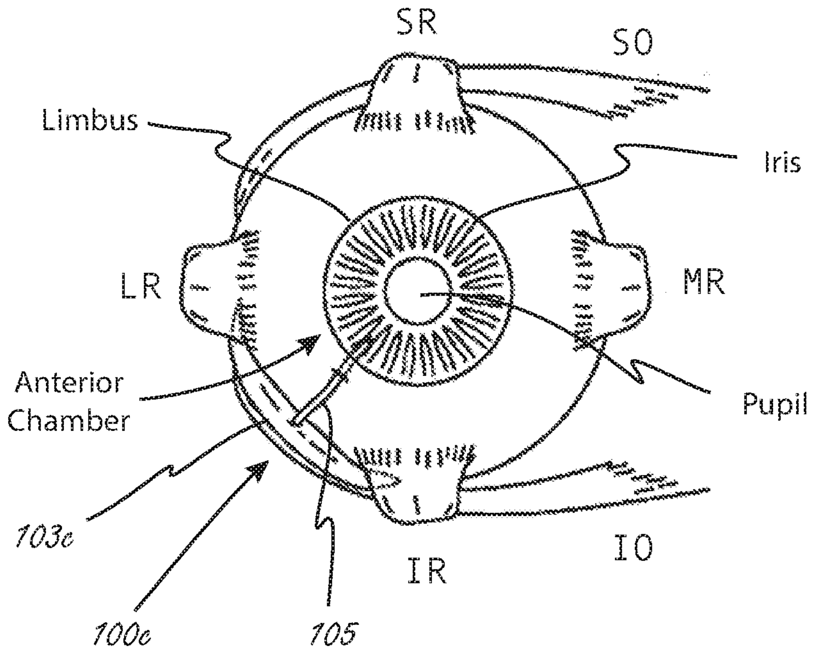

SR
SO
Limbus
Iris
LR
MR
Anterior Chamber
Pupil
103c
100c
105
IR
IO

Fig. 2A

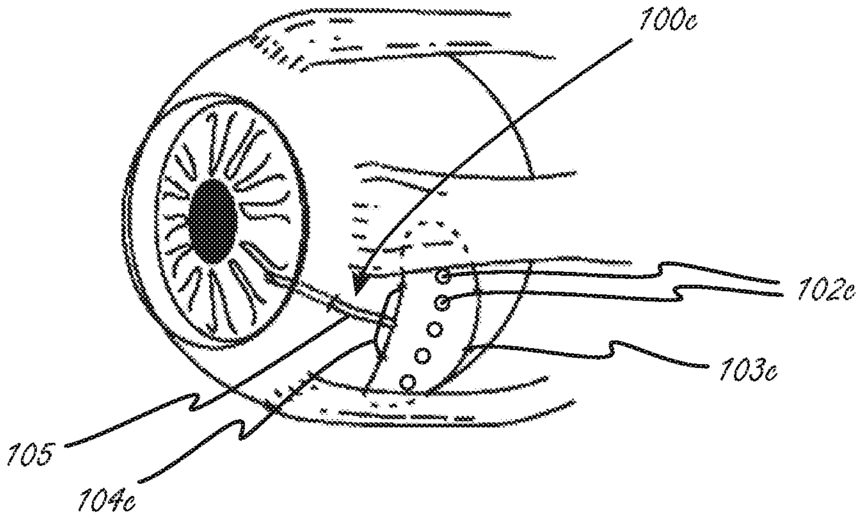

100c
102c
103c
105
104c

Fig. 2B

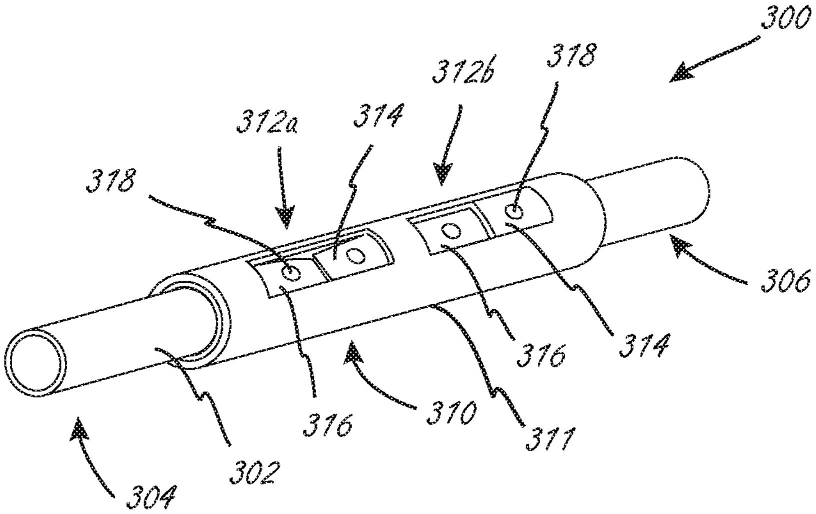

300
318
312b
312a
314
318
306
316
314
316
310
311
302
304

Fig. 3A

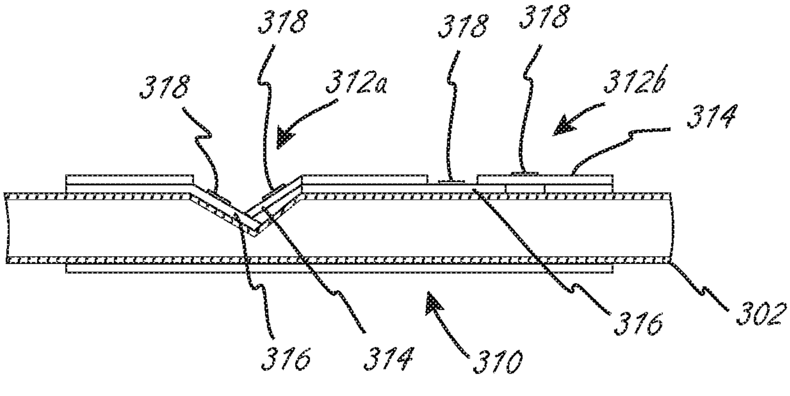

318
318
318
312a
318
312b
314
316
314
310
316
302

Fig. 3B

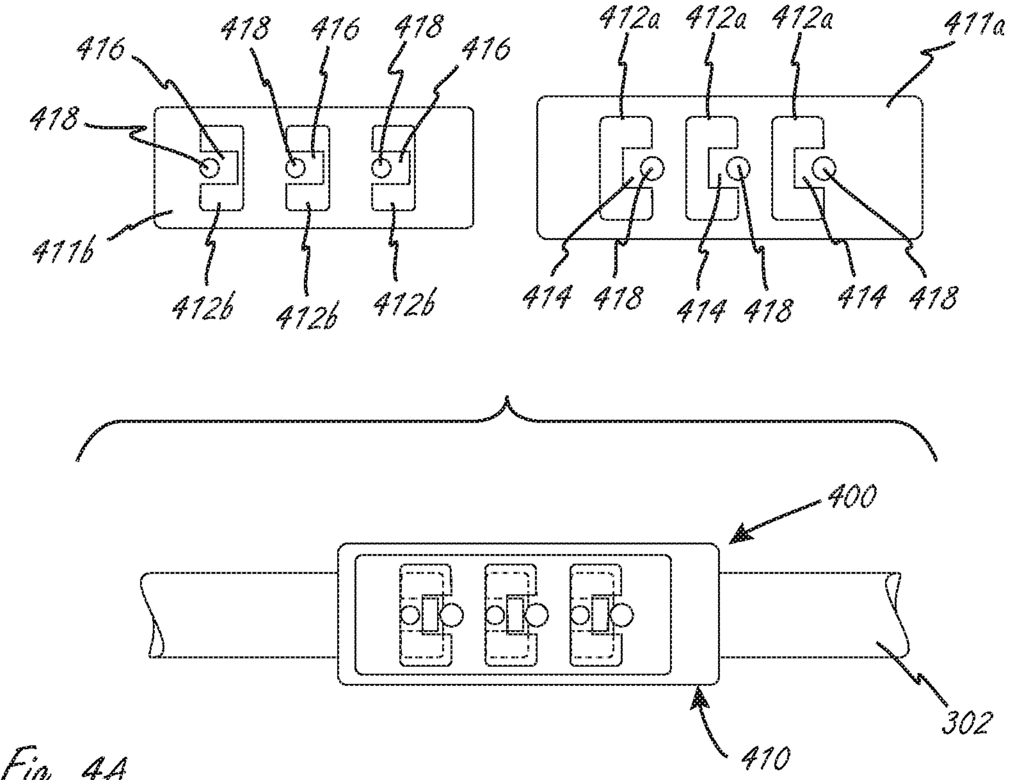

416
418
416
418
416
418
411b
412b
412b
412b
412a
412a
412a
411a
414
418
414
418
414
418
400
302
410

Fig. 4A

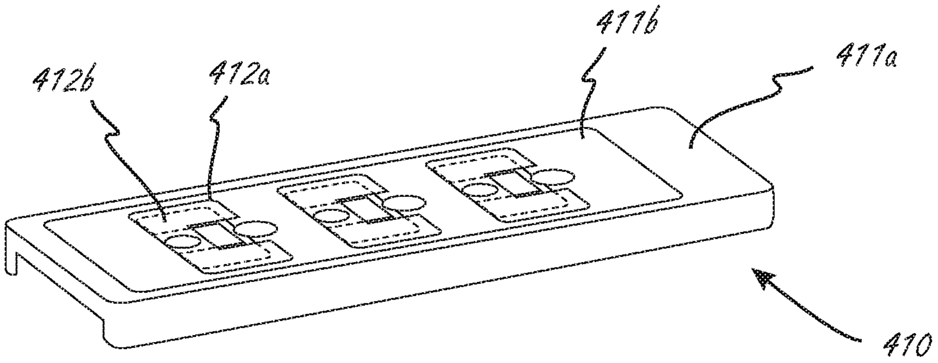

411b
412b
412a
411a
410

Fig. 4B

Fig. 5A

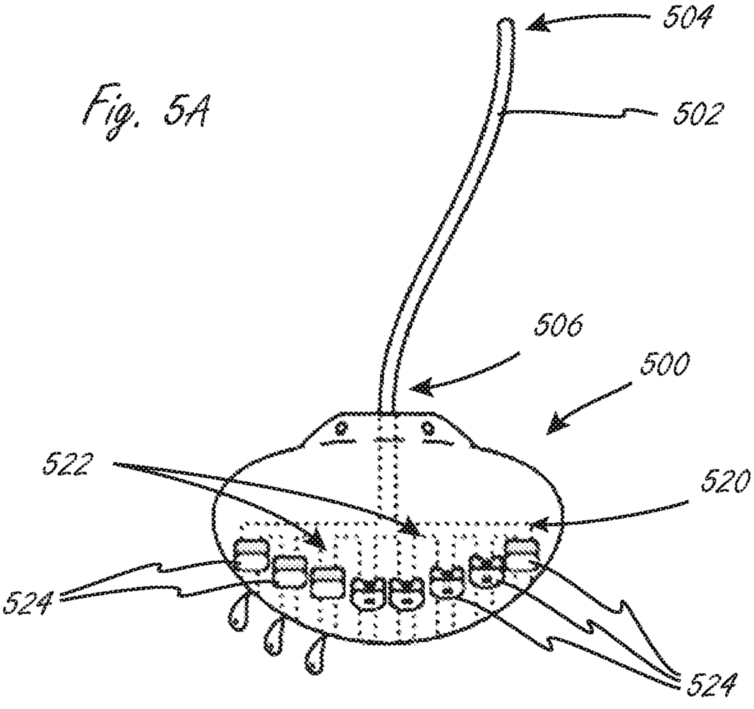


Fig. 5B

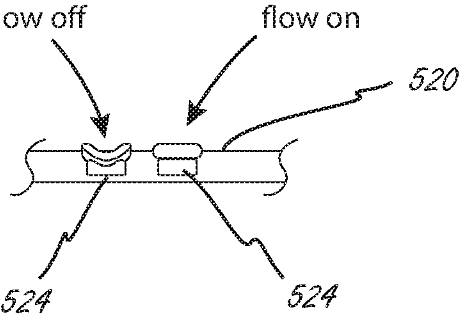
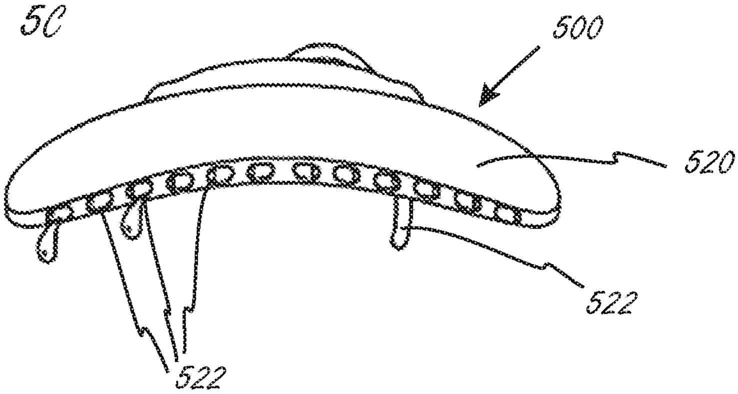


Fig. 5C



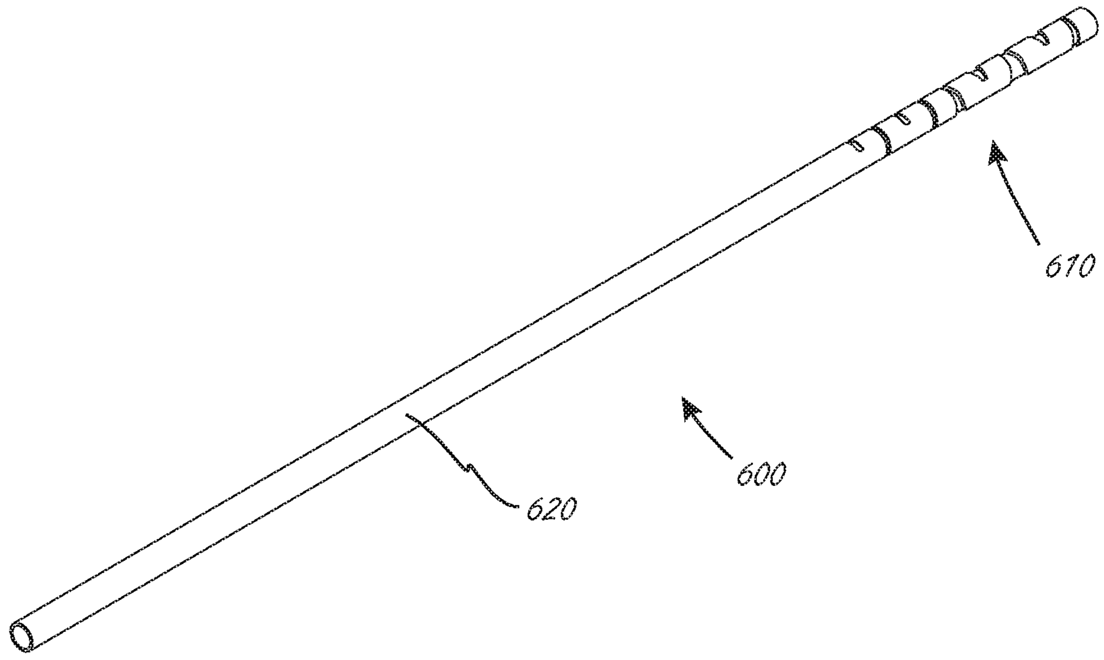


Fig. 6A

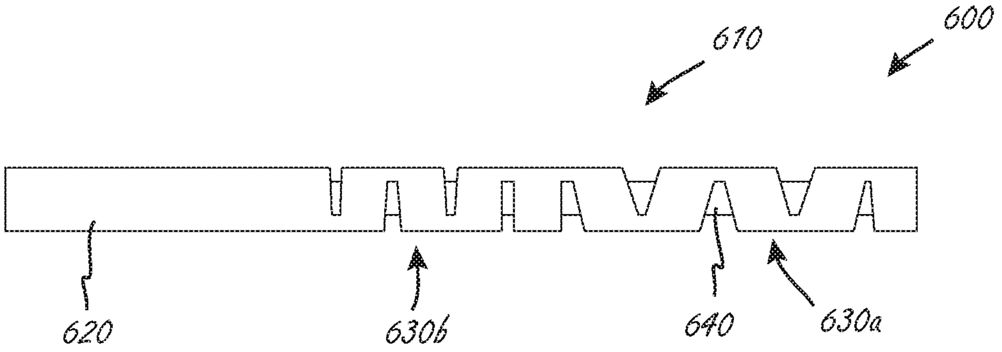


Fig. 6B

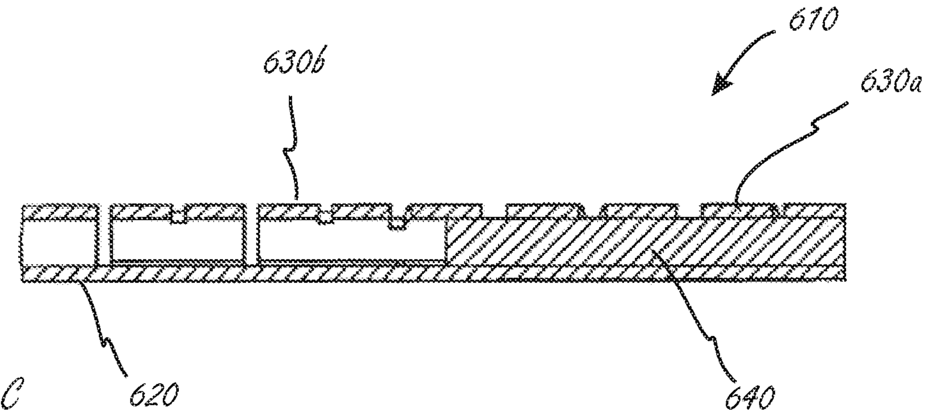


Fig. 6C

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2020/014186

A. CLASSIFICATION OF SUBJECT MATTER

A61F 9/007(2006.01)i, A61M 27/00(2006.01)i, A61L 31/14(2006.01)i

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)
A61F 9/007; A61B 17/00; A61F 9/00; A61F 9/008; A61M 27/00; A61M 37/00; A61L 31/14

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: eye, glaucoma, anterior chamber, shunt, non-invasive energy, flow

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2017-0071791 A1 (TEL HASHOMER MEDICAL RESEARCH INFRASTRUCTURE AND SERVICES LTD.) 16 March 2017 paragraphs [0027]-[0032], claims 1-5 and figure 3	1-5,7-21
Y		6,22,23
Y	US 2008-0125691 A1 (IRA YARON et al.) 29 May 2008 paragraphs [0047]-[0052] and figure 1	6,22,23
A	US 2012-0089073 A1 (EMMETT T. CUNNINGHAM, JR.) 12 April 2012 paragraphs [0035]-[0063] and figures 1A-2	1-23
A	US 2013-0150773 A1 (ODED M. NISSAN et al.) 13 June 2013 paragraphs [0021]-[0024] and figure 2	1-23
A	JP 5576427 B2 (BARONOVA INC.) 20 August 2014 claims 1-7	1-23

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:
"A" document defining the general state of the art which is not considered to be of particular relevance
"D" document cited by the applicant in the international application
"E" earlier application or patent but published on or after the international filing date
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)
"O" document referring to an oral disclosure, use, exhibition or other means
"P" document published prior to the international filing date but later than the priority date claimed
"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents,such combination being obvious to a person skilled in the art
"&" document member of the same patent family

Date of the actual completion of the international search 03 June 2020 (03.06.2020)	Date of mailing of the international search report **04 June 2020 (04.06.2020)**
Name and mailing address of the ISA/KR International Application Division Korean Intellectual Property Office 189 Cheongsa-ro, Seo-gu, Daejeon, 35208, Republic of Korea Facsimile No. +82-42-481-8578	Authorized officer Kim, Yeonkyung Telephone No. +82-42-481-3325

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2017-0071791 A1	16/03/2017	EP 3116458 A1	18/01/2017
		WO 2015-136520 A1	17/09/2015
US 2008-0125691 A1	29/05/2008	AU 1999-14191 A1	15/06/1999
		AU 2011-232403 A1	04/10/2012
		AU 2011-232403 B2	22/05/2014
		CA 2311244 A1	03/06/1999
		CA 2311244 C	17/03/2009
		CA 2793954 A1	29/09/2011
		CA 2793954 C	03/04/2018
		CN 102905655 A	30/01/2013
		CN 102905655 B	07/10/2015
		CN 1285724 A	28/02/2001
		DE 69838955 T2	18/12/2008
		EP 1032334 A1	06/09/2000
		EP 1032334 B1	02/01/2008
		EP 1920742 A2	14/05/2008
		EP 1920742 A3	26/08/2009
		EP 1920742 B1	25/12/2013
		EP 2319469 A1	11/05/2011
		EP 2319469 B1	23/01/2013
		EP 2552369 A1	06/02/2013
		EP 2552369 B1	25/01/2017
		JP 2001-523519 A	27/11/2001
		JP 2013-523213 A	17/06/2013
		JP 2016-052571 A	14/04/2016
		JP 4011850 B2	21/11/2007
		JP 5873072 B2	01/03/2016
		JP 6074011 B2	01/02/2017
		KR 10-0495373 B1	14/06/2005
		KR 10-2001-0032324 A	16/04/2001
		US 2001-0000527 A1	26/04/2001
		US 2003-0079329 A1	01/05/2003
		US 2010-0185138 A1	22/07/2010
		US 2010-0274259 A1	28/10/2010
		US 2012-0053505 A1	01/03/2012
		US 2013-0006164 A1	03/01/2013
		US 6203513 B1	20/03/2001
		US 6510600 B2	28/01/2003
		US 7670310 B2	02/03/2010
		US 8313454 B2	20/11/2012
		US 8486086 B2	16/07/2013
		US 9173774 B2	03/11/2015
		WO 2011-119834 A1	29/09/2011
		WO 99-26567 A1	03/06/1999
US 2012-0089073 A1	12/04/2012	US 8915877 B2	23/12/2014
US 2013-0150773 A1	13/06/2013	US 8771220 B2	08/07/2014

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2020/014186

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
JP 5576427 B2	20/08/2014	AU 2003-223187 A1	09/09/2003
		AU 2003-223187 B2	22/05/2008
		AU 2004-258968 A1	03/02/2005
		AU 2004-258968 B2	27/10/2011
		AU 2005-274132 A1	23/02/2006
		AU 2005-274132 B2	15/12/2011
		AU 2006-257892 A1	21/12/2006
		AU 2006-284801 A1	08/03/2007
		AU 2006-284801 B2	04/08/2011
		AU 2007-212404 A1	16/08/2007
		AU 2007-212404 B2	17/05/2012
		AU 2007-212473 A1	16/08/2007
		AU 2007-212473 B2	09/08/2012
		AU 2007-313638 A1	08/05/2008
		AU 2011-239317 A1	17/11/2011
		AU 2011-239317 B2	10/04/2014
		AU 2012-200476 A1	16/02/2012
		AU 2012-200476 B2	05/09/2013
		AU 2012-201500 A1	05/04/2012
		CA 2477054 A1	04/09/2003
		CA 2477054 C	31/05/2011
		CA 2534118 A1	03/02/2005
		CA 2534118 C	13/09/2011
		CA 2576476 A1	23/02/2006
		CA 2576476 C	20/11/2012
		CA 2611746 A1	21/12/2006
		CA 2620859 A1	08/03/2007
		CA 2620859 C	07/06/2011
		CA 2641483 A1	16/08/2007
		CA 2641625 A1	16/08/2007
		CA 2668077 A1	08/05/2008
		CA 2668077 C	29/12/2015
		CA 2744973 A1	03/02/2005
		CA 2744973 C	18/11/2014
		EP 1485146 A1	15/12/2004
		EP 1485146 A4	07/07/2010
		EP 1485146 B1	07/08/2013
		EP 1659983 A2	31/05/2006
		EP 1659983 B1	28/06/2017
		EP 1781183 A2	09/05/2007
		EP 1781183 B1	10/04/2013
		EP 1895894 A2	12/03/2008
		EP 1919370 A2	14/05/2008
		EP 1978876 A2	15/10/2008
		EP 1978876 B1	11/04/2018
		EP 1979039 A2	15/10/2008
		EP 1979039 B1	03/06/2015
		EP 2077758 A2	15/07/2009
		EP 2086466 A2	12/08/2009
		EP 2086466 A4	26/10/2011

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
		EP 2086466 B1	13/12/2017
		EP 2374487 A1	12/10/2011
		EP 2374487 B1	09/04/2014
		JP 2006-507018 A	02/03/2006
		JP 2007-500538 A	18/01/2007
		JP 2008-515464 A	15/05/2008
		JP 2009-508544 A	05/03/2009
		JP 2009-525145 A	09/07/2009
		JP 2009-525146 A	09/07/2009
		JP 2010-527247 A	12/08/2010
		JP 2012-196457 A	18/10/2012
		JP 4741490 B2	03/08/2011
		JP 5015775 B2	29/08/2012
		JP 5280211 B2	04/09/2013
		JP 5329236 B2	30/10/2013
		JP 5414528 B2	12/02/2014
		US 2005-0033331 A1	10/02/2005
		US 2005-0033332 A1	10/02/2005
		US 2005-0055039 A1	10/03/2005
		US 2006-0020278 A1	26/01/2006
		US 2007-0135831 A1	14/06/2007
		US 2007-0178160 A1	02/08/2007
		US 2007-0250132 A1	25/10/2007
		US 2009-0118757 A1	07/05/2009
		US 2009-0118758 A1	07/05/2009
		US 2009-0187200 A1	23/07/2009
		US 2009-0187201 A1	23/07/2009
		US 2009-0216262 A1	27/08/2009
		US 2009-0259236 A2	15/10/2009
		US 2009-0318844 A1	24/12/2009
		US 2011-0178455 A1	21/07/2011
		US 2013-0253409 A1	26/09/2013
		US 2013-0338565 A1	19/12/2013
		US 2013-0338566 A1	19/12/2013
		US 2015-0150561 A1	04/06/2015
		US 2016-0331947 A1	17/11/2016
		US 2017-0246018 A1	31/08/2017
		US 6994095 B2	07/02/2006
		US 7195608 B2	27/03/2007
		US 7311690 B2	25/12/2007
		US 7335179 B2	26/02/2008
		US 7621886 B2	24/11/2009
		US 7909790 B2	22/03/2011
		US 8048169 B2	01/11/2011
		US 8394048 B2	12/03/2013
		US 8398577 B2	19/03/2013
		US 8517973 B2	27/08/2013
		US 8657885 B2	25/02/2014
		US 8663338 B2	04/03/2014
		US 8771221 B2	08/07/2014

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/US2020/014186

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
		US 8821521 B2	02/09/2014
		US 8882699 B2	11/11/2014
		US 9421347 B2	23/08/2016
		US 9498366 B2	22/11/2016
		US 9510834 B2	06/12/2016
		US 9642735 B2	09/05/2017
		US 9687243 B2	27/06/2017
		US 9700450 B2	11/07/2017
		US 9913968 B2	13/03/2018
		US 9924948 B2	27/03/2018
		US 9931122 B2	03/04/2018
		WO 2005-009288 A2	03/02/2005
		WO 2005-009288 A3	04/08/2005
		WO 2005-018708 A2	03/03/2005
		WO 2005-018708 A3	24/11/2005
		WO 2006-020370 A2	23/02/2006
		WO 2006-020370 A3	24/12/2008
		WO 2006-135857 A2	21/12/2006
		WO 2006-135857 A3	26/04/2007
		WO 2007-027812 A2	08/03/2007
		WO 2007-027812 A3	23/04/2009
		WO 2007-092390 A2	16/08/2007
		WO 2007-092390 A3	21/02/2008
		WO 2007-092501 A2	16/08/2007
		WO 2007-092501 A3	24/12/2008
		WO 2008-055229 A2	08/05/2008
		WO 2008-055229 A3	07/08/2008
		WO 2008-055248 A2	08/05/2008
		WO 2008-055248 A3	03/07/2008