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(72) **Inventeurs/Inventors:**
ZIMMERMANN, RONALD R., US;
BIEL, MERRILL A., US;
MERSCH, STEVEN H., US

(73) **Propriétaire/Owner:**
ADVANCED PHOTODYNAMIC TECHNOLOGIES, INC., US

(74) **Agent:** GOWLING WLG (CANADA) LLP

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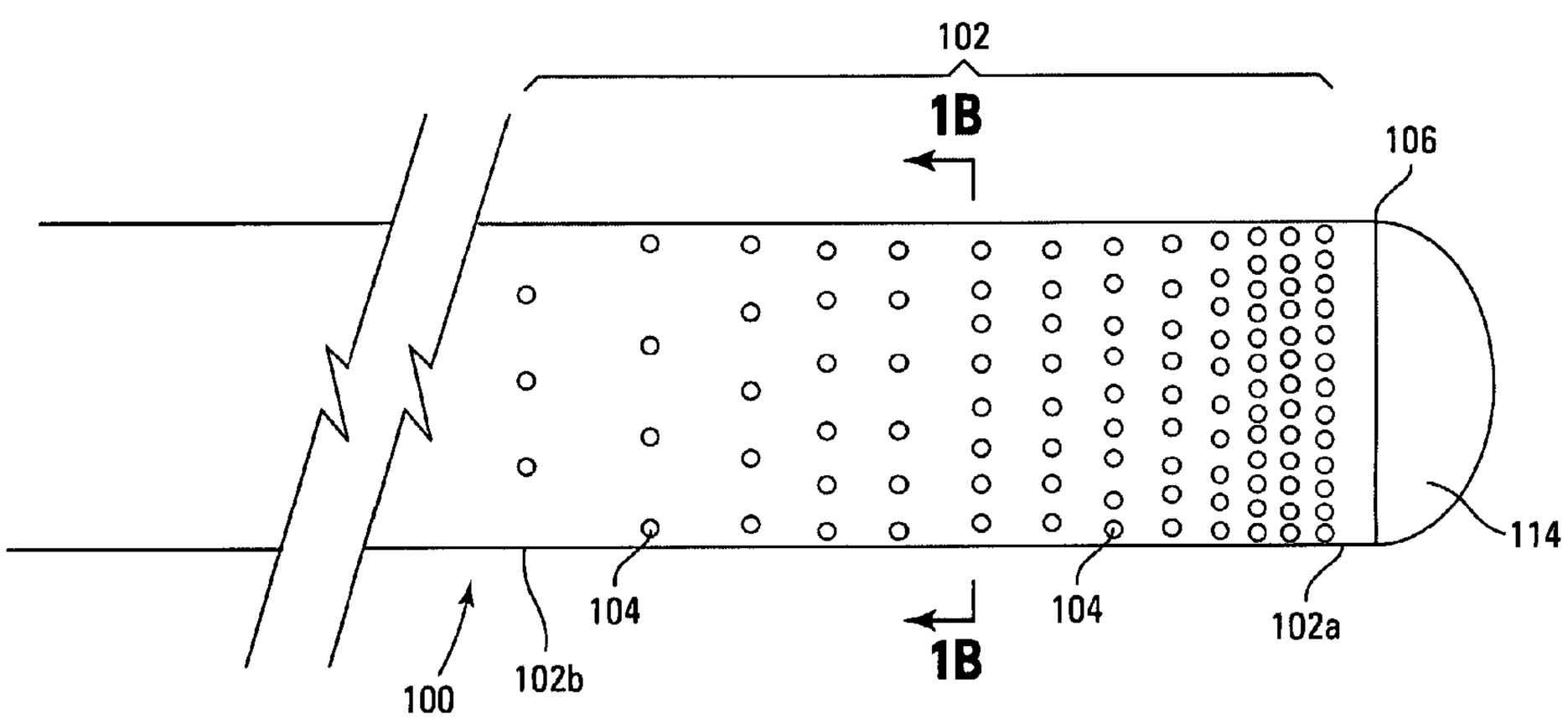

(57) **Abrégé/Abstract:**
A light diffusing device for use in photodynamic therapy has a progressively distally increased exposed amount of core fiber defining a light emitting section. Excessive light energy emission is thus prevented access to proximal locations and provides an increased amount of available light energy at distal locations, thus permitting an even emission of light energy along the light emitting section.

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(71) Applicant *(for all designated States except US)*: **ADVANCED PHOTODYNAMIC TECHNOLOGIES, INC.** [US/US]; 2715 4th Street SE, Suite 70, Minneapolis, MN 55414 (US).

(72) Inventors; and
(75) Inventors/Applicants *(for US only)*: **ZIMMERMANN, Ronald, R.** [US/US]; 3781 Smithfield Curve, Woodbury, MN 55129 (US). **BIEL, Merrill, A.** [US/US]; 2563 Delware Road, Mendota Heights, MN 55118 (US). **MERSCH, Steven, H.** [US/US]; 7347 Weaver Road, Germantown, OH 45327 (US).

(74) Agent: **EMERY, Richard, C.**; 3564 Rolling View Drive, Suite G, White Bear Lake, MN 55110-7003 (US).

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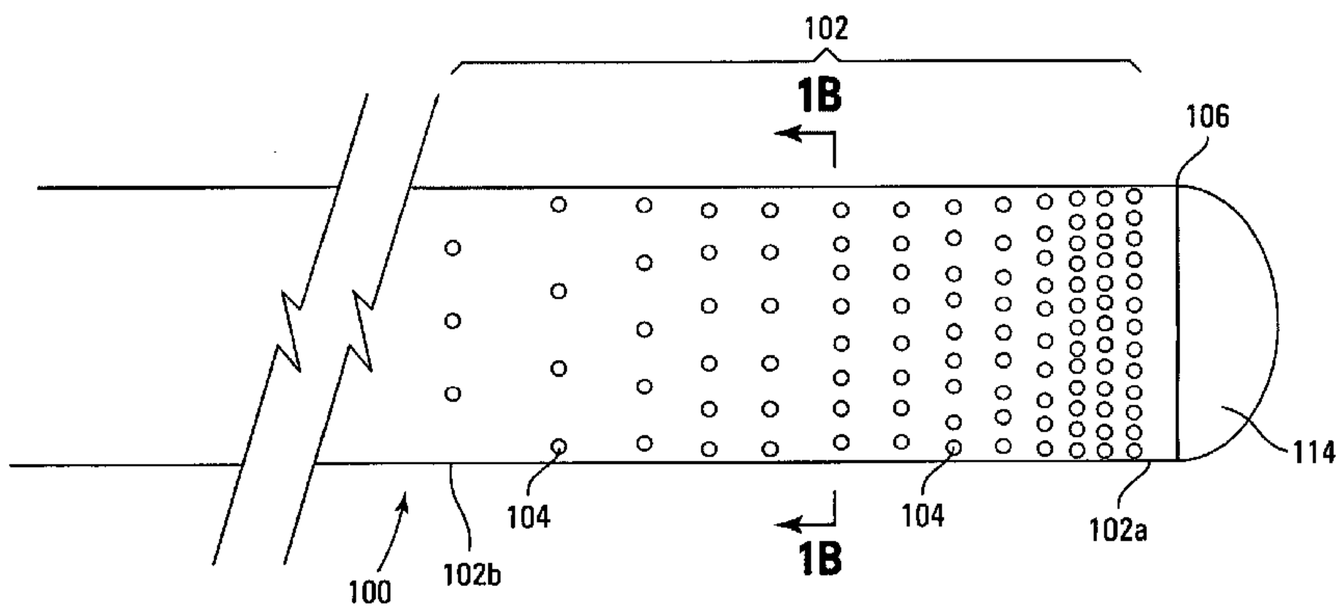

FIG. 1

(57) Abstract: A light diffusing device for use in photodynamic therapy has a progressively distally increased exposed amount of core fiber defining a light emitting section. Excessive light energy emission is thus prevented access to proximal locations and provides an increased amount of available light energy at distal locations, thus permitting an even emission of light energy along the light emitting section.

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LIGHT DIFFUSING DEVICE

GOVERNMENT LICENSE RIGHTS

The U.S. government has a paid-up license in this invention and the right in limited circumstances to require the patent owner to license others on reasonable terms as provided by the terms of Grant No. 2R44 A1041866-02A2 awarded by the National Institute of Health: National Institute of Allergy and Infectious Diseases.

FIELD OF THE INVENTION

The present invention relates to devices used for light transmission as are used in photodynamic therapy to deliver light energy to a treatment site.

BACKGROUND

Photodynamic therapy (PDT) is a medical treatment involving the use of a photosensitizing agent which is exposed to a specific wavelength of light to create oxygen radicals, resulting in the destruction of cancer cells, bacteria, viruses or fungi. A PDT system consists of three principal components: a photosensitizing agent, a light source (typically a laser) and a light delivery means (typically optical fiber based).

PDT involves the use of a photosensitizing agent that is relatively selectively concentrated in cancer cells or microbiological pathogen sites. Depending on the type of photosensistizer, it may be injected intravenously, ingested orally or applied topically. After application of the photosensitizing agent it is selectively retained by diseased tissue so that after a period of time, determined by the kinetics of the compound's distribution, there is more photosensitizing agent absorbed by the diseased tissue than in normal tissue. The photosensitizing agent is then activated by exposure to a specific wavelength of light matching the absorption rates. This results

in tissue necrosis via several mechanisms including oxygen radical production as well as vascular shutdown to the diseased tissue. Because there is less photosensitizer in the adjacent normal tissue, only the diseased tissue necroses and the normal tissue is preserved when the correct light dose rate for that tissue is administered. The advantage of PDT over conventional treatment such as surgery, radiation and chemotherapy is its relatively selective destruction of diseased tissue with normal tissue preservation.

The light distribution properties of the light delivery device can have direct impact on the effectiveness of the light application and thus the efficacy of the PDT treatment. The challenge of the light delivery devices is to ensure the light distribution is equal along the entire length of the light emitting section of the device. Several types of distributing devices have been developed in attempts to more evenly and safely distribute the light and energy radiating from the device used to deliver the laser energy. One type of diffusing device involves a fiber optic microlens which is able to transfer a divergent light beam to a limited area tissue area. A light diffusion device, as disclosed in U.S. Patent No. 4,660,925 to McCaughen, Jr. consists of a fiber cylindrical diffuser which emits a cylindrical scattering pattern of light output with respect to the cylindrical axis of the optical fiber, using a spaced series of rings of varying intensity light. Yet another diffusion device as disclosed in U.S. Patent No. 4,693,556 to McCaughen, Jr. consists of a fiber optic spherical diffuser or "light bulb" which produces a spherical scattering light field. Each of these diffusing devices produces a light field of varying intensity over the area of emitted light from the optical fiber which may result in an uneven activation of the photosensitizer over the treatment area. In still another device, as disclosed in U.S. Patents 5, 536,265 and 5,695,583 to van den Bergh et al., the cladding is removed from a plastic optical fiber and replaced by a scattering medium which may or may not be roughened, resulting in a light emission area. This device is problematic in that the distal area of the light emitting area is less intense than the more proximal areas of the light emitting area of the device. What is clearly needed, then, is an improved optical fiber that is able to more evenly deliver light energy over a wider surface area.

It is understood that the present invention as described and claimed herein can be used for many additional purposes, therefore the invention is within the scope of other fields and uses and not so limited.

SUMMARY

In one aspect, the present invention comprises a light diffusing device having an optical fiber defining a longitudinal dimension, a lateral dimension and a distal end. A core fiber is at least partially covered by cladding and a light emitting section is formed by selectively removing cladding such that a progressively distally increasing surface area of core fiber is exposed, resulting in an even distribution of light emitted from the light emitting section. The light emitting section further defines a distal end and a proximal end.

In another aspect, the present invention comprises a light diffusing device having an optical fiber defining a length, a diameter, a proximal end, a distal end and a core fiber at least partially covered by cladding. A light emitting section is formed by removing the cladding covering the light emitting section and selectively removing core fiber thereby progressively distally increasing the surface area of exposed core fiber, resulting in an even distribution of light emitted from the light emitting section. The light emitting section further defines a distal end and a proximal end.

In a further aspect, the present invention comprises a light diffusing device having an optical fiber defining a length, a diameter, a proximal end and a distal end and a core fiber at least partially covered by cladding wherein a light emitting section is formed by selectively removing cladding to form at least a single light port such that a progressively distally increasing surface area of core fiber is exposed, resulting in an even distribution of light emitted from the light emitting section. The light emitting section further defines a distal end and a proximal end.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig 1 shows the distal end of an embodiment of the light diffusing device of the present invention having a plurality of similarly sized open areas through the cladding distally progressively closer in proximity to each other.

Fig. 1A is a plan view of the light diffusing device shown in Fig. 1.

Fig. 1B is a lateral cross section taken through the lines 1B-1B as shown in Fig. 1.

Fig. 2 shows the distal end of an embodiment of the light diffusing device of the present invention having a plurality of open areas through the cladding distally increasing in size.

Fig. 2A is a plan view of the light diffusing device shown in Fig. 2.

Fig. 2B is a lateral cross section taken through the lines 2B-2B as shown in Fig. 2.

Fig. 3 shows the distal end of an embodiment of the light diffusing device of the present invention having a plurality of similarly sized open areas through the cladding distally increasing in depth into the core fiber.

Fig. 3A is a plan view of the light diffusing device shown in Fig. 3.

Fig. 3B is a lateral cross section taken through the lines 3B-3B as shown in Fig. 3, showing openings through the cladding and into the core fiber having a relatively shallow depth.

Fig. 3C is a lateral cross section taken through the lines 3C-3C as shown in Fig. 3, showing openings through the cladding and into the core fiber having a relatively intermediate depth.

Fig. 3D is a lateral cross section taken through the lines 3D-3D as shown in Fig. 3, showing openings through the cladding and into the core fiber having a relatively deep depth.

Fig. 4A is a top view of the distal end of a light diffusing device of the present invention having a continuous opening through the cladding and extending progressively distally deeper into the core fiber.

Fig. 4B is a side view of the distal end of the light diffusing device shown in Fig. 4A using phantom lines to show the continuous opening extending progressively distally deeper into the core fiber.

Fig. 4C is a plan view of the light diffusing device shown in Fig. 4.

Fig. 4D is a lateral cross section taken through the lines 4D-4D as shown in Figs. 4A-4B, showing the opening through the cladding and into the core fiber having a relatively shallow depth.

Fig. 4E is a lateral cross section taken through the lines 4E-4E as shown in Figs. 4A-4B, showing the opening through the cladding and into the core fiber having a relatively intermediate depth.

Fig. 4F is a lateral cross section taken through the lines 4F-4F as shown in Figs. 4A-4B, showing the opening through the cladding and into the core fiber having a relatively deep depth.

Fig. 5 shows the distal end of a light diffusing device of the present invention having a continuous opening extending distally wider through the cladding.

Fig. 5A is a plan view of the light diffusing device shown in Fig. 5.

Fig. 5B is a lateral cross section taken through the lines 5B-5B as shown in Fig. 5, showing the opening through the cladding and into the core fiber having a relatively narrow width.

Fig. 5C is a lateral cross section taken through the lines 5C-5C as shown in Fig. 5, showing the opening through the cladding and into the core fiber having a relatively intermediate width.

Fig. 5D is a lateral cross section taken through the lines 5D-5D as shown in Fig. 5, showing the opening through the cladding and into the core fiber having a relatively wide width.

Fig 6 shows the distal end of an embodiment of the light diffusing device of the present invention having an exposed core fiber at the distal end with a plurality of similarly sized removed core fiber sections distally progressively closer in proximity to each other.

Fig. 6A is a plan view of the light diffusing device shown in Fig. 6.

Fig. 6B is a lateral cross section taken through the lines 6B-6B as shown in Fig. 6.

Fig. 7 shows the distal end of an embodiment of the light diffusing device of the present invention having an exposed core fiber at the distal end with a plurality of removed core fiber sections distally increasing in size.

Fig. 7A is a plan view of the light diffusing device shown in Fig. 7.

Fig. 7B is a lateral cross section taken through the lines 7B-7B as shown in Fig. 7.

Fig. 8 shows the distal end of an embodiment of the light diffusing device of the present invention having an exposed core fiber at the distal end with a plurality of similarly sized removed core fiber sections distally increasing in depth into the core fiber.

Fig. 8A is a plan view of the light diffusing device shown in Fig. 8.

Fig. 8B is a lateral cross section taken through the lines 8B-3B as shown in Fig. 8, showing removed core fiber sections and into the core fiber having a relatively shallow depth.

Fig. 8C is a lateral cross section taken through the lines 8C-8C as shown in Fig. 8, showing removed core fiber sections and into the core fiber having a relatively intermediate depth.

Fig. 8D is a lateral cross section taken through the lines 8D-8D as shown in Fig. 8, showing removed core fiber sections and into the core fiber having a relatively deep depth.

Fig. 9A is a top view of the distal end of a light diffusing device of the present invention having an exposed core fiber at the distal end with a continuous removed core fiber section extending progressively distally deeper into the core fiber.

Fig. 9B is a side view of the distal end of the light diffusing device shown in Fig. 9A using phantom lines to show the continuous opening extending progressively distally deeper into the core fiber.

Fig. 9C is a plan view of the light diffusing device shown in Fig. 9.

Fig. 9D is a lateral cross section taken through the lines 9D-9D as shown in Fig. 9, showing the removed core fiber section extending into the core fiber to a relatively shallow depth.

Fig. 9E is a lateral cross section taken through the lines 9E-9E as shown in Fig. 9, showing the removed core fiber section extending into the core fiber to a relatively intermediate depth.

Fig. 9F is a lateral cross section taken through the lines 9F-9F as shown in Fig. 9, showing the removed core fiber section extending into the core fiber to a relatively deep depth.

Fig. 10 shows the distal end of a light diffusing device of the present invention having an exposed core fiber at the distal end with a continuous removed core fiber section extending distally wider across the core fiber.

Fig. 10A is a plan view of the light diffusing device shown in Fig. 10.

Fig. 10B is a lateral cross section taken through the lines 10B-10B as shown in Fig. 10, showing the removed core fiber section extending into the core fiber to a relatively narrow width.

Fig. 10C is a lateral cross section taken through the lines 10C-10C as shown in Fig. 10, showing the removed core fiber section extending into the core fiber to a relatively intermediate width.

Fig. 10D is a lateral cross section taken through the lines 10D-10D as shown in Fig. 10, showing the removed core fiber section extending into the core fiber to a relatively wide width.

Fig. 11 shows the distal end of an embodiment of the light diffusing device of the present invention having an exposed core fiber at the distal end with the exposed core fiber progressively distally rougher.

Fig. 11A is a plan view of the light diffusing device shown in Fig. 11.

Fig 12 shows the distal end of an embodiment of the light diffusing device of the present invention having a plurality of similarly sized open areas through the cladding distally progressively closer in proximity to each other. A piercing tip is attached to the distal end of the device.

Fig. 12A is a plan view of the light diffusing device shown in Fig. 12.

Fig. 12B is a lateral cross section taken through the lines 12B-12B as shown in Fig. 12.

Fig. 13A is a top view of the distal end of a light diffusing device of the present invention having a continuous opening through the cladding and extending progressively distally deeper into the core fiber. A piercing tip is attached to the distal end of the device. Fluorescent material is embedded in the sheathing.

Fig. 13B is a side view of the distal end of the light diffusing device shown in Fig. 13A using phantom lines to show the continuous opening extending progressively distally deeper into the core fiber.

Fig. 13C is a plan view of the light diffusing device shown in Figs. 13A-13B.

Fig. 13D is a lateral cross section taken through the lines 13D-13D as shown in Figs. 13A-13B, showing the opening through the cladding and into the core fiber having a relatively shallow depth.

Fig. 13E is a lateral cross section taken through the lines 13E-13E as shown in Figs. 13A-13B, showing the opening through the cladding and into the core fiber having a relatively intermediate depth.

Fig. 13F is a lateral cross section taken through the lines 13F-13FD as shown in Figs. 13A-13B, showing the opening through the cladding and into the core fiber having a relatively deep depth.

Fig. 14 shows the distal end of a light diffusing device of the present invention having a continuous opening extending distally wider through the cladding. The device is sheathed and a piercing tip is attached to the distal end of the device.

Fig. 14A is a plan view of the light diffusing device shown in Fig. 14.

Fig. 14B is a lateral cross section taken through the lines 14B-14B as shown in Fig. 14, showing the opening through the sheathing and cladding and into the core fiber having a relatively narrow width.

Fig. 14C is a lateral cross section taken through the lines 14C-14C as shown in Fig. 14, showing the opening through the sheathing and cladding and into the core fiber having a relatively intermediate width.

Fig. 14D is a lateral cross section taken through the lines 14D-14D as shown in Fig. 14, showing the opening through the sheathing and cladding and into the core fiber having a relatively wide width.

Fig. 15 shows the distal end of an embodiment of the light diffusing device of the present invention having a plurality of open areas through the cladding distally increasing in size. The device is sheathed and a piercing tip is attached to the distal end of the device. Fluorescent material is embedded in the sheathing.

Fig. 15A is a plan view of the light diffusing device shown in Fig. 15.

Fig. 15B is a lateral cross section taken through the lines 15B-15B as shown in Fig. 15.

Fig. 16 shows the distal end of an embodiment of the light diffusing device of the present invention having a plurality of similarly sized open areas through the cladding distally increasing in depth into the core fiber. The device is sheathed and the sheathing is configured on the distal end to be able to pierce tissue. Fluorescent material is embedded in the sheathing.

Fig. 16A is a plan view of the light diffusing device shown in Fig. 16.

Fig. 16B is a lateral cross section taken through the lines 16B-16B as shown in Fig. 16, showing openings through the cladding and into the core fiber having a relatively shallow depth.

Fig. 16C is a lateral cross section taken through the lines 16C-16C as shown in Fig. 16, showing openings through the cladding and into the core fiber having a relatively intermediate depth.

Fig. 16D is a lateral cross section taken through the lines 16D-16D as shown in Fig. 16, showing openings through the cladding and into the core fiber having a relatively deep depth.

Fig. 17 shows the distal end of an embodiment of the light diffusing device of the present invention having cladding covering the light diffusing section with the exposed cladding progressively distally rougher.

Fig. 17A is a plan view of the light diffusing device shown in Fig. 17.

Fig. 17B is a lateral cross section taken through the lines 17B-17B as shown in Fig. 17, showing openings through the cladding core fiber.

DETAILED DESCRIPTION

The particulars shown herein are by way of example and for purposes of illustrative discussion of the invention only and are presented in the cause of providing what is believed to be the most useful and readily understood description of the principles and conceptual aspects of the invention. In this regard, no attempt is made to show structural details of the invention in more detail than is necessary for the fundamental understanding of the invention, the description taken with the drawings making apparent to those skilled in the art how the several forms of the invention may be embodied in practice.

Nomenclature

10 Optical Fiber
100 Light Diffusing Device
102 Light Emitting Section
102a Distal End (Light Emitting Section)
102b Proximal End (Light Emitting Section)
104 Light Port
105 Proximal End
106 Distal End
108 Cladding
110 Core Fiber

112 Connector

114 End Piece

200 Light Diffusing Device

202 Light Emitting Section

202a Distal End (Light Emitting Section)

202b Proximal End (Light Emitting Section)

204 Light Port

205 Proximal End

206 Distal End

208 Cladding

210 Core Fiber

212 Connector

214 End Piece

300 Light Diffusing Device

302 Light Emitting Section

302a Distal End (Light Emitting Section)

302b Proximal End (Light Emitting Section)

304 Light Port

305 Proximal End

306 Distal End

308 Cladding

310 Core Fiber

312 Connector

314 End Piece

400 Light Diffusing Device

402 Light Emitting Section

402a Distal End (Light Emitting Section)

402b Proximal End (Light Emitting Section)

404 Light Port

405 Proximal End

406 Distal End

408 Cladding

410 Core Fiber

412 Connector

414 End Piece

500 Light Diffusing Device

502 Light Emitting Section

502a Distal End (Light Emitting Section)

502b Proximal End (Light Emitting Section)

504 Light Port

505 Proximal End

506 Distal End

508 Cladding

510 Core Fiber

512 Connector

514 End Piece

600 Light Diffusing Device

602 Light Emitting Section

602a Distal End (Light Emitting Section)

602b Proximal End (Light Emitting Section)

604 Removed Core Fiber Section

605 Proximal End

606 Distal End

608 Cladding

610 Core Fiber

612 Connector

614 End Piece

700 Light Diffusing Device

702 Light Emitting Section

702a Distal End (Light Emitting Section)

702b Proximal End (Light Emitting Section)

704 Removed Core Fiber Section

705 Proximal End

706 Distal End

708 Cladding

710 Core Fiber

712 Connector

714 Piercing Tip

800 Light Diffusing Device

802 Light Emitting Section

802a Distal End (Light Emitting Section)

802b Proximal End (Light Emitting Section)

804 Removed Core Fiber Section

805 Proximal End

806 Distal End

808 Cladding

810 Core Fiber

812 Connector

814 End Piece

900 Light Diffusing device

902 Light Emitting Section

902a Distal End (Light Emitting Section)

902b Proximal End (Light Emitting Section)

904 Removed Core Fiber Section

905 Proximal End

906 Distal End

908 Cladding

910 Core Fiber

912 Connector

914 End Piece

1000 Light Diffusing Device

1002 Light Emitting Section

1002a Distal End (Light Emitting Section)

1002b Proximal End (Light Emitting Section)

1004 Removed Core Fiber Section

1005 Proximal End

1006 Distal End

1008 Cladding

1010 Core Fiber

1012 Connector

1014 End Piece

1100 Light Diffusing Device

1102 Light Emitting Section

1102a Distal End (Light Emitting Section)

1102b Proximal End (Light Emitting Section)

1104a Rougher Section of Core Fiber

1104b Smoother Section of Core Fiber

1105 Proximal End

1106 Distal End

1108 Cladding

1110 Core Fiber

1112 Connector

1114 End Piece

1200 Light Diffusing device

1202 Light Emitting Section

1202a Distal End (Light Emitting Section)

1202b Proximal End (Light Emitting Section)

1204 Light Port

1205 Proximal End

1206 Distal End

1208 Cladding

1210 Core Fiber

1212 Connector

1214 Piercing Tip

1300 Light Diffusing device

1302 Light Emitting Section

1302a Distal End (Light Emitting Section)

1302b Proximal End (Light Emitting Section)

1304 Light Port

1305 Proximal End

1306 Distal End

1308 Cladding

1310 Core Fiber

1312 Connector

1314 Piercing Tip

1316 Fluorescent Material

1400 Light Diffusing device

1402 Light Emitting Section

1402a Distal End (Light Emitting Section)

1402b Proximal End (Light Emitting Section)

1404 Light Port

1405 Proximal End

1406 Distal End

1408 Cladding

1410 Core Fiber

1412 Connector

1414 Piercing Tip

1418 Sheathing

1500 Light Diffusing device

1502 Light Emitting Section

1502a Distal End (Light Emitting Section)

1502b Proximal End (Light Emitting Section)

1504 Light Port

1505 Proximal End

1506 Distal End

1508 Cladding

1510 Core Fiber

1512 Connector

1514 Piercing Tip

1516 Fluorescent Material

1518 Sheathing

1600 Light Diffusing device

1602 Light Emitting Section

1602a Distal End (Light Emitting Section)

1602b Proximal End (Light Emitting Section)

1604 Light Port

1605 Proximal End

1606 Distal End

1608 Cladding

1610 Core Fiber

1612 Connector

1614 Piercing Distal End

1616 Fluorescent Material

1618 Sheathing

1700 Light Diffusing Device

1702 Light Emitting Section

1702a Distal End (Light Emitting Section)

1702b Proximal End (Light Emitting Section)

1704a Rougher Section of Light Emitting Section

1704b Smoother Section of Light Emitting Section

1705 Proximal End

1706 Distal End

1708 Cladding

1710 Core Fiber

1712 Connector

1714 End Piece

Definitions

"Distal" means further from the point controlled by the operator (e.g., physician or technician) of a device.

"Opaque" means absorbing light energy in a particular wavelength range.

"Proximal" means closer to the point controlled by the operator (e.g., physician or technician) of a device.

Construction

Fig. 1 shows the light emitting section **102** of an embodiment of a light diffusing device **100** of the present invention. Fig. 1A shows the entire light diffusing device **100**, including a connector **112** attached to the proximal end **105** allowing the light diffusing device **100** to be connected to a light source (not shown). As best

shown in Fig. 1B the light diffusing device **100** is made for reasons of economy as well as flexibility from a plastic optical fiber **10** approximately 1mm in diameter which comprises a light transmitting core fiber **110** made of PMMA (acrylic) surrounded by cladding **108** made of fluorinated polymers. It should be mentioned that other kinds of light transmitting fibers (not shown) could also be used and are therefore contemplated by and within the scope of the invention. The core fiber **110** and cladding **108** have different indexes of refraction, which enables light entering the light diffusing device **100** at the connector **112** to be transmitted along the length of the light diffusing device **100** and therefore transmitted to a more distal location. The light diffusing device **100** defines a distal end **106** to which is attached an opaque end piece **114**, preventing the escape of the transmitted light energy from an otherwise open distal end (not shown) of the core fiber **110**. In one embodiment, the end piece **114** can be made of stainless steel. Using appropriate medical grade adhesives, the end piece **114** is attached to the distal end **106** of the optical fiber **10** after the distal end **106** is roughened by such means as sandpaper, sandblasting, chemical degradation or other abrasive or erosive methods. In another embodiment (not shown) the end piece **114** may be omitted and replaced by other light blocking mechanisms including opaque epoxy or plastic materials. In an alternative embodiment (not shown) the light diffusing device **100** may be encased in a transparent protective sheath (not shown) which provides an additional degree of integrity as well as smoothness.

The light emitting section **102** is defined by a plurality of light ports **104** which extend through the cladding **108** exposing the core fiber **110**, thereby allowing the transmitted light energy to be emitted from the light diffusing device **100**. As best shown in Fig. 1, the light emitting section **102** is characterized by the light ports **104** having a similar surface area and progressively denser in distribution (greater in number) as the distal end **102a** is reached. As shown in Fig. 1B the light ports **104** are round shaped and spacing may vary between 0.022 inches to 0.040 inches. Restated, a denser distribution of similarly sized light ports **104** at the distal end **102a** results in a lesser exposed core fiber **110** surface area at the proximal end **102b** of the light emitting section **102** and a greater exposed core fiber **110** surface area at the distal end **102a** of the light emitting section **102**, allowing a greater quantity of light to be available at the distal end **102a** of the light emitting section **102**. The reason for this

is that if the distribution of light ports **104** was even (not shown), more light would be emitted from the more proximally located light ports **104**, leaving less light available to be emitted from the more distally located light ports **104**. The result of evenly distributed light ports **104** (not shown) would be a device (not shown) having uneven light distribution, with more intensity toward the proximal end and less toward the distal end. The embodiment of the light diffusing device **100** shown in Figs. 1-1B thus evenly emits the transmitted light energy along the length of the light emitting section **102**, allowing safer and more precise photodynamic therapy.

Fig. 2 shows the light emitting section **202** of an embodiment of a light diffusing device **200** of the present invention. Fig. 2A shows the entire light diffusing device **200**, including a connector **212** attached to the proximal end **205** allowing the light diffusing device **200** to be connected to a light source (not shown). As best shown in Fig. 2B the light diffusing device **200** is made for reasons of economy as well as flexibility from a plastic optical fiber **10** approximately 1mm in diameter which comprises a light transmitting core fiber **210** made of PMMA (acrylic) surrounded by cladding **208** made of fluorinated polymers. It should be mentioned that other kinds of light transmitting fibers (not shown) could also be used and are therefore contemplated by and within the scope of the invention. The core fiber **210** and cladding **208** have different indexes of refraction, which enables light entering the light diffusing device **200** at a proximal location to be transmitted along the length of the light diffusing device **200** and thereby transmitted to a more distal location. The light diffusing device **200** defines a distal end **206** which comprises an opaque end piece **214**, preventing the escape of the transmitted light energy from the core fiber **210**. In one embodiment the end piece **214** is made of stainless steel. In this embodiment a section of fluorescent material **216** is placed between the end piece **214** and the distal end **206** of the optical fiber **10**. The fluorescent material **216** can be made of chromium crystal, however, this is not intended to be limiting as other materials including alexandrite, sapphire and others would also work. Using appropriate medical grade adhesives, the fluorescent material **216** is attached to the distal end **206** of the optical fiber **10** after the distal end **206** is roughened by such means as sandpaper, sandblasting, chemical degradation or other abrasive or erosive methods. Following attachment of the fluorescent material **216** to the optical fiber **10**, the opaque end piece **214** is attached to the distal end (unnumbered) of the fluorescent

material **216** using appropriate medical grade adhesives. The end piece **214** prevents the escape of light energy through the distal end **206**. The fluorescent material **216** emits a signal when illuminated by light energy having a wavelength at least at an excitation wavelength and above and thus functions as a fluorescence feedback indicator. In this configuration, when the laser light source (not shown) is energized, fluorescence occurs at the distal end **206** and is detected at the light source console (not shown) to verify the light diffusing device **200** is valid and functioning properly. In another embodiment (not shown) the end piece **214** may be omitted and replaced by other light blocking mechanisms including opaque epoxy or plastic materials. In an alternative embodiment (not shown) the light diffusing device **200** may be encased in a transparent protective sheath (not shown) which provides an additional degree of integrity as well as smoothness.

The light emitting section **202** is defined by a plurality of light ports **204** which extend through the cladding **208** exposing the core fiber **210** allowing the transmitted light energy to be emitted from the light diffusing device **200**. As best shown in Fig. 2, the light emitting section **202** is characterized by the light ports **204** progressively defining a greater surface area as the distal end **206** is reached. The light ports **204** are conically shaped and spacing may vary in diameter between 0.003 inches to 0.006 inches. Restated, progressively greater sized light ports **204** toward the distal end **202a** result in a lesser exposed core fiber **210** surface area at the proximal end **202b** of the light emitting section **202** and a greater exposed core fiber **210** surface area at the distal end **202a** of the light emitting section **202**, allowing a greater quantity of light to be available at the distal end **206** of the light emitting section **202**. The reason for this is that if the surface area of the light ports **204** was consistent (not shown), more light would be emitted from the more proximally located light ports **204**, leaving less light available to be emitted from the more distally located light ports **204**. The result of similarly sized light ports **204** (not shown) would be a device (not shown) having uneven light distribution, with more intensity toward the proximal end and less toward the distal end. The embodiment of the light diffusing device **200** shown in Figs. 2-2B thus evenly emits the transmitted light energy along the length of the light emitting section **202**, allowing safer and more precise photodynamic therapy.

Fig. 3 shows the light emitting section **302** of an embodiment of a light diffusing device **300** of the present invention. Fig. 3A shows the entire light diffusing device **300**, including a connector **312** attached to the proximal end **305** allowing the light diffusing device **300** to be connected to a light source (not shown). As best shown in Figs. 3B, 3C, 3D the light diffusing device **300** is made for reasons of economy as well as flexibility from a plastic optical fiber **10** approximately 1mm in diameter which comprises a light transmitting core fiber **310** made of PMMA (acrylic) surrounded by cladding **308** made of fluorinated polymers. It should be mentioned that other kinds of light transmitting fibers (not shown) could also be used and are therefore contemplated by and within the scope of the invention. The core fiber **310** and cladding **308** have different indexes of refraction, which enables light entering the light diffusing device **300** at the connector **312** to be transmitted along the length of the light diffusing device **300** and thereby transmitted to a more distal location. The light diffusing device **300** defines a distal end **306** to which is attached an opaque end piece **314**, preventing the escape of the transmitted light energy from an open distal end (not shown) of the core fiber **310**. The end piece **314** can be made of stainless steel. Using appropriate medical grade adhesives, the end piece **314** is attached to the distal end **306** of the light diffusing device **300** after the distal end **306** of the optical fiber **10** is roughened by such means as sandpaper, sandblasting, chemical degradation or other abrasive or erosive methods. In another embodiment (not shown) the end piece **314** may be omitted and replaced by other light blocking mechanisms including opaque epoxy or plastic materials. In an alternative embodiment (not shown) the light diffusing device **300** may be encased in a transparent protective sheath (not shown) which provides an additional degree of integrity as well as smoothness.

The light emitting section **302** is defined by a plurality of light ports **304** which extend through the cladding **308** into the core fiber **300** allowing the transmitted light to be emitted from the light diffusing device **300**. As best shown in Figs. 3B, 3C, 3D, the light emitting section **302** is characterized by the light ports **304** having a similar surface area and progressively deeper into the core fiber **310** as the distal end **302a** is reached, thus exposing a greater amount of core fiber **310**. The light ports **304** are conically shaped and the depth may vary between 0.004 inches to 0.008 inches. Restated, progressively deeper, similarly sized light ports **304** toward

the distal end **302a** result in a lesser exposed core fiber **310** surface area at the proximal end **302b** of the light emitting section **302** and a greater exposed core fiber **310** surface area at the distal end **302a** of the light emitting section **302**, allowing a greater quantity of light to be available at the distal end **302a** of the light emitting section **302**. The reason for this is that if the size and depth of light ports **304** was consistent (not shown), more light would be emitted from the more proximally located light ports **304**, leaving less light available to be emitted from the more distally located light ports **304**. The result of similarly sized and depth light ports **304** (not shown) would be a device (not shown) having uneven light distribution, with more intensity toward the proximal end and less toward the distal end. The embodiment of the light diffusing device **300** shown in Fig. 3 thus evenly emits the transmitted light energy along the length of the light emitting section **302**, allowing safer and more precise photodynamic therapy.

Fig. 4A shows a top view of the light emitting section **402** of an embodiment of the light diffusing device **400** of the present invention. A side view is shown in Fig. 4B, with phantom lines indicating the location and depth of the light port **404**. Fig. 4C shows the entire light diffusing device **400**, including a connector **412** attached to the proximal end **405** allowing the light diffusing device **400** to be connected to a light source (not shown). As best shown in Figs. 4D, 4E, 4F the light diffusing device **400** is made for reasons of economy as well as flexibility from a plastic optical fiber **10** approximately 1mm in diameter which comprises a light transmitting core fiber **410** made of PMMA (acrylic) surrounded by cladding **408** made of fluorinated polymers. It should be mentioned that other kinds of light transmitting fibers (not shown) could also be used and are therefore contemplated by and within the scope of the invention. The core fiber **410** and cladding **408** have different indexes of refraction, which enables light entering the light diffusing device **400** at the connector **412** to be transmitted along the length of the light diffusing device **400** and thereby transmitted to a more distal location. The light diffusing device **400** defines a distal end **406** which comprises an opaque end piece **414**, preventing the escape of the transmitted light energy from an otherwise open distal end (not shown) of the core fiber **410**. In one embodiment, the end piece **414** is made of stainless steel. Using appropriate medical grade adhesives, the end piece **414** is attached to the distal end **406** of the optical fiber **10** after the distal end **406** is

roughened by such means as sandpaper, sandblasting, chemical degradation or other abrasive methods. In another embodiment (not shown) the end piece **414** may be omitted and replaced by other light blocking mechanisms including opaque epoxy or plastic materials. In an alternative embodiment (not shown) the light diffusing device **400** may be encased in a transparent protective sheath (not shown) which provides an additional degree of integrity as well as smoothness.

The light emitting section **402** is defined by an extended light port **404** which is cut through the cladding **408** into the core fiber **400** allowing the transmitted light to be emitted from the light diffusing device **400**. While a single extended light port **404** is shown in Figs. 4-4F, this is for purposes of illustration only and the invention could also include multiple extended light ports **404** (not shown). As best shown in Figs. 4D, 4E, 4F, the light emitting section **402** is characterized by the light port **404** extending progressively deeper into the core fiber **410** as the distal end **402a** is reached. Restated, the progressively deeper light port **404** toward the distal end **402a** results in a lesser exposed core fiber **410** surface area at the proximal end **402b** of the light emitting section **402** and a greater exposed core fiber **410** surface area at the distal end **402a** of the light emitting section **402**, allowing a greater quantity of light to be available at the distal end (unnumbered) of the light emitting section **402**. The reason for this is that if the depth of the light port **404** was consistent (not shown), more light would be emitted from the proximal end of the light port **404**, leaving less light available to be emitted from the distal end of the light port **404**. The result of a uniform depth light port **404** (not shown) would be an optical fiber (not shown) having uneven light distribution, with more intensity toward the proximal end and less toward the distal end. The embodiment of the light diffusing device **400** shown in Fig. 4 thus evenly emits the transmitted light energy along the length of the light emitting section **402**, allowing safer and more precise photodynamic therapy.

Fig. 5 shows the light emitting section **502** of an embodiment of the light diffusing device **500** of the present invention. Fig. 5A shows the entire light diffusing device **500**, including a connector **512** attached to the proximal end **505** allowing the light diffusing device **500** to be connected to a light source (not shown). As best shown in Figs. 5B, 5C, 5D the light diffusing device **500** is made for reasons of economy as well as flexibility from a plastic optical fiber **10** approximately 1mm in

diameter which comprises a light transmitting core fiber **510** made of PMMA (acrylic) surrounded by cladding **508** made of fluorinated polymers. It should be mentioned that other kinds of light transmitting fibers (not shown) could also be used and are therefore contemplated by and within the scope of the invention. The core fiber **510** and cladding **508** have different indexes of refraction, which enables light entering the light diffusing device **500** at the connector **512** to be transmitted along the length of the light diffusing device **500** and thereby transmitted to a more distal location. The light diffusing device **500** defines a distal end **506** to which is attached an opaque end piece **514**, preventing the escape of the transmitted light energy from an open distal end (not shown) of the core fiber **510**. In one embodiment, the end piece **514** is made of stainless steel. Using appropriate medical grade adhesives, the end piece **514** is attached to the distal end **506** of the optical fiber **10** after the distal end **506** is roughened by such means as sandpaper, sandblasting, chemical degradation or other abrasive or erosive methods. In another embodiment (not shown) the end piece **514** may be omitted and replaced by other light blocking mechanisms including opaque epoxy or plastic materials. In an alternative embodiment (not shown) the light diffusing device **500** may be encased in a transparent protective sheath (not shown) which provides an additional degree of integrity as well as smoothness.

The light emitting section **502** is defined by an extended light port **504** which is cut through the cladding **508** exposing the core fiber **500** allowing the transmitted light to be emitted from the light diffusing device **500**. While a single extended light port **504** is shown in Figs. 5-5D, this is for purposes of illustration only and the invention could also include multiple extended light ports **504** (not shown). As best shown in Figs. 5B, 5C, 5D, the light emitting section **502** is characterized by the light port **504** extending progressively wider through the cladding **508** as the distal end is reached. Restated, the progressively wider light port **504** toward the distal end results in a lesser exposed core fiber **510** surface area at the proximal end **502b** of the light emitting section **502** and a greater exposed core fiber **510** surface area at the distal end **502a** of the light emitting section **502**, allowing a greater quantity of light to be available at the distal end **502a** of the light emitting section **502**. The reason for this is that if the width of the light port **504** was consistent (not shown), more light would be emitted from the proximal end **502b** of the light port **504**, leaving less light

available to be emitted from the distal end **502a** of the light port **504**. The result of a uniform width light port **504** (not shown) would be an optical fiber (not shown) having uneven light distribution, with more intensity toward the proximal end and less toward the distal end. The embodiment of the light diffusing device **500** shown in Fig. 5 thus evenly emits the transmitted light energy along the length of the light emitting section **502**, allowing safer and more precise photodynamic therapy.

Fig. 6 shows the light emitting section **602** of an embodiment of a light diffusing device **600** of the present invention. Fig. 6A shows the entire light diffusing device **600**, including a connector **612** attached to the proximal end **605** allowing the light diffusing device **600** to be connected to a light source (not shown). As best shown in Fig. 6B the light diffusing device **600** is made for reasons of economy as well as flexibility from a plastic optical fiber **10** approximately 1mm in diameter which comprises a light transmitting core fiber **610** made of PMMA (acrylic) surrounded by cladding **608** made of fluorinated polymers. It should be mentioned that other kinds of light transmitting fibers (not shown) could also be used and are therefore contemplated by and within the scope of the invention. The core fiber **610** and cladding **608** have different indexes of refraction, which enables light entering the light diffusing device **600** at the connector **612** to be transmitted along the length of the light diffusing device **600** and therefore transmitted to a more distal location. The light diffusing device **600** defines a distal end **606** to which is attached an opaque end piece **614**, preventing the escape of the transmitted light energy from an open distal end (not shown) of the core fiber **610**. In one embodiment, the end piece **614** is made of stainless steel. Using appropriate medical grade adhesives, the end piece **614** is attached to the distal end **606** of the optical fiber **10** after the distal end **606** is roughened by such means as sandpaper, sandblasting, chemical degradation or other abrasive or erosive methods. In another embodiment (not shown) the end piece **614** may be omitted and replaced by other light blocking mechanisms including opaque epoxy or plastic materials. In an alternative embodiment (not shown) the light diffusing device **600** may be encased in a transparent protective sheath (not shown) which provides an additional degree of integrity as well as smoothness.

In this embodiment the light diffusing device **600** has an exposed section of core fiber **610** which defines the light emitting section **602**. The light emitting section

602 is further defined by a plurality of removed core fiber sections **604** which extend into the core fiber **610** allowing additional transmitted light energy to be emitted from the light diffusing device **600** as a result of a greater exposed surface area of the core fiber **604**. As best shown in Fig. 6, the light emitting section **602** is characterized by the removed core fiber sections **604** having a similar surface area and progressively denser in distribution (greater in number) as the distal end **602a** is reached. As shown in Fig. 6B the removed core fiber sections **604** are conical and spacing may vary between 0.022 inches to 0.040 inches. Restated, a denser distribution of similarly sized removed core fiber sections **604** at the distal end **602a** results in a lesser exposed core fiber **610** surface area at the proximal end **602b** of the light emitting section **602** and a greater exposed core fiber **610** surface area at the distal end **602a** of the light emitting section **602**, allowing a greater quantity of light to be available at the distal end **602a** of the light emitting section **602**. The reason for this is that if the distribution of removed core fiber sections **604** was even (not shown), more light would be emitted from the more proximally located removed core fiber sections **604**, leaving less light available to be emitted from the more distally located removed core fiber sections **604**. The result of evenly distributed removed core fiber sections **604** (not shown) would be an optical fiber (not shown) having uneven light distribution, with more intensity toward the proximal end and less toward the distal end. The embodiment of the light diffusing device **600** shown in Figs. 6-6B thus evenly emits the transmitted light energy along the length of the light emitting section **602**, allowing safer and more precise photodynamic therapy.

Fig. 7 shows the light emitting section **702** of an embodiment of a light diffusing device **700** of the present invention. Fig. 7A shows the entire light diffusing device **700**, including a connector **712** attached to the proximal end **705** allowing the light diffusing device **700** to be connected to a light source (not shown). As best shown in Fig. 7B the light diffusing device **700** is made for reasons of economy as well as flexibility from a plastic optical fiber **10** approximately 1mm in diameter which comprises a light transmitting core fiber **710** made of PMMA (acrylic) surrounded by cladding **708** made of fluorinated polymers. It should be mentioned that other kinds of light transmitting fibers (not shown) could also be used and are therefore contemplated by and within the scope of the invention. The core fiber **710** and cladding **708** have different indexes of refraction, which enables light entering the

light diffusing device **700** at a proximal location to be transmitted along the length of the light diffusing device **700** and thereby transmitted to a more distal location. The light diffusing device **700** defines a distal end **706** to which is attached a piercing tip **714**, preventing the escape of the transmitted light energy from an open distal end (not shown) of the core fiber **710**. The piercing tip **714** also allows the device **700** to pierce or penetrate and thereby be implanted into tissue following the application of gentle force by the physician. In one embodiment, the piercing tip **714** is made of machined (sharpened) stainless steel and also functions to pierce or penetrate tissue as required for treatment. Using appropriate medical grade adhesives, the piercing tip **714** is attached to the distal end **706** of the optical fiber **10** after the distal end **706** is roughened by such means as sandpaper, sandblasting, chemical degradation or other abrasive or erosive methods. In an alternative embodiment (not shown) the light diffusing device **700** may be encased in a transparent protective sheath (not shown) which provides an additional degree of integrity as well as smoothness.

In this embodiment the light diffusing device **700** has an exposed section of core fiber **710** which defines the light emitting section **702**. The light emitting section **702** is further defined by a plurality of removed core fiber sections **704** which extend into the core fiber **710** allowing additional transmitted light energy to be emitted from the light diffusing device **700**. As best shown in Fig. 7, the light emitting section **702** is characterized by the removed core fiber sections **704** being similarly numbered and progressively defining a greater surface area as the distal end **706** is reached. The removed core fiber sections **704** are conically shaped and spacing may vary in diameter between 0.003 inches to 0.006 inches. Restated, progressively greater sized removed core fiber sections **704** toward the distal end **702a** result in a lesser exposed core fiber **710** surface area at the proximal end **702b** of the light emitting section **702** and a greater exposed core fiber **710** surface area at the distal end **702a** of the light emitting section **702**, allowing a greater quantity of light to be available at the distal end **706** of the light emitting section **702**. The reason for this is that if the exposed surface area of the removed core fiber sections **704** was consistent (not shown), more light would be emitted from the more proximally located removed core fiber sections **704**, leaving less light available to be emitted from the more distally located removed core fiber sections **704**. The result of similarly sized removed core fiber sections **704** (not shown) would be an optical fiber (not shown) having uneven light distribution,

with more intensity toward the proximal end and less toward the distal end. The embodiment of the light diffusing device **700** shown in Figs. 7-7B thus evenly emits the transmitted light energy along the length of the light emitting section **702**, allowing safer and more precise photodynamic therapy.

Fig. 8 shows the light emitting section **802** of an embodiment of a light diffusing device **800** of the present invention. Fig. 8A shows the entire light diffusing device **800**, including a connector **812** attached to the proximal end **805** allowing the light diffusing device **800** to be connected to a light source (not shown). As best shown in Figs. 8C, 8D, 8E the light diffusing device **800** is made for reasons of economy as well as flexibility from a plastic optical fiber **10** approximately 1mm in diameter which comprises a light transmitting core fiber **810** made of PMMA (acrylic) surrounded by cladding **808** made of fluorinated polymers. It should be mentioned that other kinds of light transmitting fibers (not shown) could also be used and are therefore contemplated by and within the scope of the invention. The core fiber **810** and cladding **808** have different indexes of refraction, which enables light entering the light diffusing device **800** at the connector **812** to be transmitted along the length of the light diffusing device **800** and thereby transmitted to a more distal location. In this embodiment a section of fluorescent material **816** is placed between the end piece **814** and the distal end **806** of the optical fiber **10**. The fluorescent material **816** can be made of chromium crystal, however, this is not intended to be limiting as other materials including alexandrite, sapphire and others would also work. Using appropriate medical grade adhesives, the fluorescent material **816** is attached to the distal end **806** of the optical fiber **10** after the distal end **806** is roughened by such means as sandpaper, sandblasting, chemical degradation or other abrasive or erosive methods. Following attachment of the fluorescent material **816** to the optical fiber **10**, the opaque end piece **814** is attached to the distal end (unnumbered) of the fluorescent material **816** using appropriate medical grade adhesives. The end piece **814** prevents the escape of light energy through the distal end **806**. The fluorescent material **816** emits a signal when illuminated by light energy having a wavelength at least at an excitation wavelength and above and thus functions as a fluorescence feedback indicator. In this configuration, when the laser light source (not shown) is energized fluorescence occurs at the distal end **806** and is detected at the light source console (not shown) to verify the light diffusing device

800 is valid and functioning properly. In another embodiment (not shown) the end piece **814** may be omitted and replaced by other light blocking mechanisms including opaque epoxy or plastic materials. In an alternative embodiment (not shown) the light diffusing device **800** may be encased in a transparent protective sheath (not shown) which provides an additional degree of integrity as well as smoothness.

In this embodiment the light diffusing device **800** has an exposed section of core fiber **810** which defines the light emitting section **802**. The light emitting section **802** is further defined by a plurality of removed core fiber sections **804** which extend through into the core fiber **800** allowing the transmitted light to be emitted from the light diffusing device **810**. As best shown in Figs. 8C, 8D, 8E the light emitting section **802** is characterized by the removed core fiber sections **804** having a similar surface area and extends progressively deeper into the core fiber **810** as the distal end **802a** is reached. The removed core fiber sections **804** are conically shaped and the depth may vary between 0.004 inches to 0.008 inches. Restated, progressively deeper, similarly sized removed core fiber sections **804** toward the distal end **802a** result in a lesser exposed core fiber **810** surface area at the proximal end **802b** of the light emitting section **802** and a greater exposed core fiber **810** surface area at the distal end **802a** of the light emitting section **802**, allowing a greater quantity of light to be available at the distal end **802a** of the light emitting section **802**. The reason for this is that if the size and depth of removed core fiber sections **804** was consistent (not shown), more light would be emitted from the more proximally located removed core fiber sections **804**, leaving less light available to be emitted from the more distally located removed core fiber sections **804**. The result of similarly sized and depth removed core fiber sections **804** (not shown) would be a light diffusing device (not shown) having uneven light distribution, with more intensity toward the proximal end and less toward the distal end. The embodiment of the light diffusing device **800** shown in Fig. 8 thus evenly emits the transmitted light energy along the length of the light emitting section **802**, allowing safer and more precise photodynamic therapy.

Fig. 9A shows a top view of the light emitting section **902** of an embodiment of the light diffusing device **900** of the present invention. A side view of the light emitting section **902** is shown in Fig. 9B, with phantom lines indicating the depth of the continuous removed core fiber section **904**. Fig. 9C shows the entire light

diffusing device **900**, including a connector **912** attached to the proximal end **905** allowing the light diffusing device **900** to be connected to a light source (not shown). As best shown in Figs. 9A, 9B the light diffusing device **900** is made for reasons of economy as well as flexibility from a plastic optical fiber **10** approximately 1mm in diameter which comprises a light transmitting core fiber **910** made of PMMA (acrylic) surrounded by cladding **908** made of fluorinated polymers. It should be mentioned that other kinds of light transmitting fibers (not shown) could also be used and are therefore contemplated by and within the scope of the invention. The core fiber **910** and cladding **908** have different indexes of refraction, which enables light entering the light diffusing device **900** at the connector **912** to be transmitted along the length of the light diffusing device **900** and thereby transmitted to a more distal location. The light diffusing device **900** defines a distal end **906** to which is attached an opaque end piece **914**, preventing the escape of the transmitted light energy from an otherwise open distal end (not shown) of the core fiber **910**. In one embodiment, the end piece **914** is made of stainless steel. Using appropriate medical grade adhesives, the end piece **914** is attached to the distal end **906** of the optical fiber **10** after the distal end **906** is roughened by such means as sandpaper, sandblasting, chemical degradation or other abrasive methods. In another embodiment (not shown) the end piece **914** may be omitted and replaced by other light blocking mechanisms including opaque epoxy or plastic materials. In an alternative embodiment (not shown) the light diffusing device **900** may be encased in a transparent protective sheath (not shown) which provides an additional degree of integrity as well as smoothness.

In this embodiment the light diffusing device **900** has an exposed section of core fiber **910** which defines the light emitting section **902**. The light emitting section **902** is further defined by an extended removed core fiber section **904** which is cut into the core fiber **910** allowing an increased amount of transmitted light to be emitted from the light diffusing device **900**. While a single extended removed core fiber section **904** is shown in Figs. 9-9F, this is for purposes of illustration only and the invention could also include multiple extended removed core fiber sections **904** (not shown). As best shown in Figs. 9D, 9E, 9F, the light emitting section **902** is characterized by the removed core fiber section **904** extending progressively deeper into the core fiber **910** as the distal end **902a** is reached. Restated, the progressively

deeper removed core fiber section **904** toward the distal end **902a** results in a lesser exposed core fiber **910** surface area at the proximal end **902b** of the light emitting section **902** and a greater exposed core fiber **910** surface area at the distal end **902a** of the light emitting section **902**, allowing a greater quantity of light to be available at the distal end **902a** of the light emitting section **902**. The reason for this is that if the depth of the removed core fiber section **904** was consistent (not shown), more light would be emitted from the proximal end of the removed core fiber section **904**, leaving less light available to be emitted from the distal end of the removed core fiber section **904**. The result of a uniform depth removed core fiber section **904** (not shown) would be alight diffusing device (not shown) having uneven light distribution, with more intensity toward the proximal end and less toward the distal end. The embodiment of the light diffusing device **900** shown in Fig. 9 thus evenly emits the transmitted light energy along the length of the light emitting section **902**, allowing safer and more precise photodynamic therapy.

Fig. 10 shows the light emitting section **1002** of an embodiment of the light diffusing device **1000** of the present invention. Fig. 10A shows the entire light diffusing device **1000**, including a connector **1012** attached to the proximal end **1005** allowing the light diffusing device **1000** to be connected to a light source (not shown). As best shown in Fig. 10 the light diffusing device **1000** is made for reasons of economy as well as flexibility from a plastic optical fiber **10** approximately 1mm in diameter which comprises a light transmitting core fiber **1010** made of PMMA (acrylic) surrounded by cladding **1008** made of fluorinated polymers. It should be mentioned that other kinds of light transmitting fibers (not shown) could also be used and are therefore contemplated by and within the scope of the invention. The core fiber **1010** and cladding **1008** have different indexes of refraction, which enables light entering the light diffusing device **1000** at the connector **1012** to be transmitted along the length of the light diffusing device **1000** and thereby transmitted to a more distal location. The light diffusing device **1000** defines a distal end **1006** to which is attached an opaque end piece **1014**, preventing the escape of the transmitted light energy from an open distal end (not shown) of the core fiber **1010**. In one embodiment, the end piece **1014** is made of stainless steel. Using appropriate medical grade adhesives, the end piece **1014** is attached to the distal end **1006** of the optical fiber **10** after the distal end **1006** is roughened by such means as sandpaper,

sandblasting, chemical degradation or other abrasive methods. In another embodiment (not shown) the end piece **1014** may be omitted and replaced by other light blocking mechanisms including opaque epoxy or plastic materials. In an alternative embodiment (not shown) the light diffusing device **1000** may be encased in a transparent protective sheath (not shown) which provides an additional degree of integrity as well as smoothness.

In this embodiment the light diffusing device **1000** has an exposed section of core fiber **1010** which defines the light emitting section **1002**. The light emitting section **1002** is further defined by an extended removed core fiber section **1004** which is cut into the core fiber **1010** exposing a distally increased surface of core fiber **1010**, allowing an increased amount of transmitted light to be emitted from the light diffusing device **1000**. While a single extended removed core fiber section **1004** is shown in Figs. 10-10D, this is for purposes of illustration only and the invention could also include multiple extended removed core fiber sections **1004** (not shown). As best shown in Figs. 10, 10A, 10B, 10C, 10D, the light emitting section **1002** is characterized by the removed core fiber section **1004** extending progressively wider into the core fiber **1010** as the distal end **1002a** is reached. Restated, the progressively wider removed core fiber section **1004** toward the distal end **1002a** results in a lesser exposed core fiber **1010** surface area at the proximal end **1002b** of the light emitting section **1002** and a greater exposed core fiber **1010** surface area at the distal end **1002a** of the light emitting section **1002**, allowing a greater quantity of light to be available at the distal end **1002a** of the light emitting section **1002**. The reason for this is that if the width and depth of the removed core fiber section **1004** was consistent (not shown), more light would be emitted from the proximal end **1002b** of the removed core fiber section **1004**, leaving less light available to be emitted from the distal end of the removed core fiber section **1004**. The result of a uniform width/depth removed core fiber section **1004** (not shown) would be a light diffusing device (not shown) having uneven light distribution, with more intensity toward the proximal end **1002b** and less toward the distal end **1002a**. The embodiment of the light diffusing device **1000** shown in Fig. 10 thus evenly emits the transmitted light energy along the length of the light emitting section **1002**, allowing safer and more precise photodynamic therapy.

Fig. 11 shows the light emitting section **1102** of an embodiment of the light diffusing device **1100** of the present invention. A plan view of the light emitting section as shown in Fig. 11A shows the entire light diffusing device **1100**, including a connector **1112** attached to the proximal end **1105** allowing the light diffusing device **1100** to be connected to a light source (not shown). As best shown in Fig. 9 the light diffusing device **1100** is made for reasons of economy as well as flexibility from a plastic optical fiber **10** approximately 1mm in diameter which comprises a light transmitting core fiber **1110** made of PMMA (acrylic) surrounded by cladding **1108** made of fluorinated polymers. It should be mentioned that other kinds of light transmitting fibers (not shown) could also be used and are therefore contemplated by and within the scope of the invention. The core fiber **1110** and cladding **1108** have different indexes of refraction, which enables light entering the light diffusing device **1100** at the connector **1112** to be transmitted along the length of the light diffusing device **1100** and thereby transmitted to a more distal location. The light diffusing device **1100** defines a distal end **1106** which comprises an opaque end piece **1114**, preventing the escape of the transmitted light energy from an open distal end (not shown) of the core fiber **1110**. In one embodiment, the end piece **1114** is made of stainless steel. Using appropriate medical grade adhesives, the end piece **1114** is attached to the distal end **1106** of the light diffusing device **1100** after the distal end **1106** is roughened by such means as sandpaper, sandblasting, chemical degradation or other abrasive methods. In another embodiment (not shown) the end piece **1114** may be omitted and replaced by other light blocking mechanisms including opaque epoxy or plastic materials. In an alternative embodiment (not shown) the light diffusing device **1100** may be encased in a transparent protective sheath (not shown) which provides an additional degree of integrity as well as smoothness.

In this embodiment the light diffusing device **1100** has an exposed section of core fiber **1110** which defines the light emitting section **1102**. The light emitting section **1102** is further defined by progressively distally roughening the surface of the light emitting section **1102** allowing an increased amount of transmitted light to be emitted from the light diffusing device **1100**. As best shown in Fig.11 the light emitting section **1102** is characterized by the light emitting section **1102** having a relatively smooth area **1104b** which becomes progressively rougher **1104a** along the core fiber **1110** as the distal end **1102a** is reached. Restated, the progressively

rougher light emitting section **1102** toward the distal end **1102a** results in a lesser exposed core fiber **1110** surface area at the proximal end **1102b** of the light emitting section **1102** and a greater exposed core fiber **1110** surface area at the distal end **1102a** of the light emitting section **1102**, allowing a greater quantity of light to be available at the distal end (unnumbered) of the light emitting section **1102**. The reason for this is that if the roughness of the light emitting section **1102** was consistent (not shown), more light would be emitted from the proximal end of the light emitting section **1102**, leaving less light available to be emitted from the distal end of the light emitting section **1102**. The result of a uniform roughness light emitting section **1102** (not shown) would be a light diffusing device (not shown) having uneven light distribution, with more intensity toward the proximal end and less toward the distal end. The embodiment of the light diffusing device **1100** shown in Fig. 11 thus evenly emits the transmitted light energy along the length of the light emitting section **1102**, allowing safer and more precise photodynamic therapy.

Fig. 12 shows the light emitting section **1202** of an embodiment of a light diffusing device **1200** of the present invention. Fig. 12A shows the entire light diffusing device **1200**, including a connector **1212** attached to the proximal end **1205** allowing the light diffusing device **1200** to be connected to a light source (not shown). As best shown in Fig. 12B the light diffusing device **1200** is made for reasons of economy as well as flexibility from a plastic optical fiber **10** approximately 1mm in diameter which comprises a light transmitting core fiber **1210** made of PMMA (acrylic) surrounded by cladding **1208** made of fluorinated polymers. It should be mentioned that other kinds of light transmitting fibers (not shown) could also be used and are therefore contemplated by and within the scope of the invention. The core fiber **1210** and cladding **1208** have different indexes of refraction, which enables light entering the light diffusing device **1200** at the connector **1212** to be transmitted along the length of the light diffusing device **1200** and therefore transmitted to a more distal location. The light diffusing device **1200** defines a distal end **1206** to which is attached a piercing tip **1214**, which prevents the escape of the transmitted light energy from an open distal end (not shown) of the core fiber **1210**. The piercing tip **1214** also allows the device **1200** to pierce or penetrate and thereby be implanted into tissue following the application of gentle force by the physician. In one embodiment, the piercing tip **1214** is made of machined (sharpened) stainless steel, however, this is not

intended to be limiting as other metallic, composite and polymeric materials would also work. Using appropriate medical grade adhesives, the piercing tip **1214** is attached to the distal end **1206** of the optical fiber **10** after the distal end **1206** is roughened by such means as sandpaper, sandblasting, chemical degradation or other abrasive or erosive methods.

The light emitting section **1202** is defined by a plurality of light ports **1204** which extend through the cladding **1208** exposing core fiber **1210** allowing the transmitted light energy to be emitted from the light diffusing device **1200**. As best shown in Fig. 12, the light emitting section **1202** is characterized by the light ports **1204** having a similar surface area and progressively denser in distribution (greater in number) as the distal end **1202a** is reached. As shown in Fig. 12B the light ports **1204** are conically shaped and spacing may vary between 0.022 inches to 0.040 inches. Restated, a denser distribution of similarly sized light ports **1204** at the distal end **1202a** results in a lesser exposed core fiber **1210** surface area at the proximal end **1202b** of the light emitting section **1202** and a greater exposed core fiber **1210** surface area at the distal end **1202a** of the light emitting section **1202**, allowing a greater quantity of light to be available at the distal end **1202a** of the light emitting section **1202**. The reason for this is that if the distribution of light ports **1204** was even (not shown), more light would be emitted from the more proximally located light ports **1204**, leaving less light available to be emitted from the more distally located light ports **1204**. The result of evenly distributed light ports **1204** (not shown) would be an optical fiber (not shown) having uneven light distribution, with more intensity toward the proximal end and less toward the distal end. The embodiment of the light diffusing device **1200** shown in Figs. 12-12B thus evenly emits the transmitted light energy along the length of the light emitting section **1202**, allowing safer and more precise photodynamic therapy.

Fig. 13A shows a top view of the light emitting section **1302** of an embodiment of the light diffusing device **1300** of the present invention. A side view is shown in Fig. 13B, with phantom lines indicating the location and depth of the light port **1304**. Fig. 13C shows the entire light diffusing device **1300**, including a connector **1312** attached to the proximal end **1305** allowing the light diffusing device **1300** to be connected to a light source (not shown). As best shown in Figs. 13D, 13E,

13F the light diffusing device **1300** is made for reasons of economy as well as flexibility from a plastic optical fiber **10** approximately 1mm in diameter which comprises a light transmitting core fiber **1310** made of PMMA (acrylic) surrounded by cladding **1308** made of fluorinated polymers. It should be mentioned that other kinds of light transmitting fibers (not shown) could also be used and are therefore contemplated by and within the scope of the invention. The core fiber **1310** and cladding **1308** have different indexes of refraction, which enables light entering the light diffusing device **1300** at the connector **1312** to be transmitted along the length of the light diffusing device **1300** and thereby transmitted to a more distal location. The light diffusing device **1300** defines a distal end **1306** to which is attached a piercing tip **1314**, preventing the escape of the transmitted light energy from an open distal end (not shown) of the core fiber **1310**. The piercing tip **1314** also allows the device **1300** to pierce or penetrate and thereby be implanted into tissue following the application of gentle force by the physician. The piercing tip **1314** in one embodiment is made of machined (sharpened) stainless steel, however, other metallic, composite and polymeric materials are also contemplated by and therefore within the scope of the invention. In this embodiment a section of fluorescent material **1316** is placed between the piercing tip **1314** and the distal end **1306** of the optical fiber **10**. The fluorescent material **1316** can be made of chromium crystal, however, this is not intended to be limiting as other materials including alexandrite, sapphire and others would also work. Using appropriate medical grade adhesives, the fluorescent material **1316** is attached to the distal end **1306** of the optical fiber **10** after the distal end **1306** is roughened by such means as sandpaper, sandblasting, chemical degradation or other abrasive or erosive methods. Following attachment of the fluorescent material **1316** to the optical fiber **10**, the piercing tip **1314** is attached to the distal end (unnumbered) of the fluorescent material **1316** using appropriate medical grade adhesives. The piercing tip **1314** prevents the escape of light energy through the distal end **1306** as well as facilitating direct introduction into tissue. The fluorescent material **1316** emits a signal when illuminated by light energy having a wavelength at least at an excitation wavelength and above and thus functions as a fluorescence feedback indicator. In this configuration, when the laser light source (not shown) is energized fluorescence occurs at the distal end **1306** and is detected at the light source console (not shown) to verify the light diffusing device **1300** is valid and functioning properly. In an alternative embodiment (not shown) the light diffusing device **1300**

may be encased in a transparent protective sheath (not shown) which provides an additional degree of integrity as well as smoothness.

The light emitting section **1302** is defined by an extended light port **1304** which is cut through the cladding **1308** into the core fiber **1300** allowing the transmitted light to be emitted from the light diffusing device **1300**. While a single extended light port **1304** is shown in Figs. 13-13F, this is for purposes of illustration only and the invention could also include multiple extended light ports **1304** (not shown). As best shown in Figs. 13D, 13E, 13F, the light emitting section **1302** is characterized by the light port **1304** extending progressively deeper into the core fiber **1310** as the distal end **1302a** is reached. Restated, the progressively deeper light port **1304** toward the distal end **1302a** results in a lesser exposed core fiber **1310** surface area at the proximal end **1302b** of the light emitting section **1302** and a greater exposed core fiber **1310** surface area at the distal end **1302a** of the light emitting section **1302**, allowing a greater quantity of light to be available at the distal end (unnumbered) of the light emitting section **1302**. The reason for this is that if the depth of the light port **1304** was consistent (not shown), more light would be emitted from the proximal end of the light port **1304**, leaving less light available to be emitted from the distal end of the light port **1304**. The result of a uniform depth light port **1304** (not shown) would be an optical fiber (not shown) having uneven light distribution, with more intensity toward the proximal end and less toward the distal end. The embodiment of the light diffusing device **1300** shown in Fig. 13 thus evenly emits the transmitted light energy along the length of the light emitting section **1302**, allowing safer and more precise photodynamic therapy.

Fig. 14 shows the light emitting section **1402** of an embodiment of the light diffusing device **1400** of the present invention. Fig. 14A shows the entire light diffusing device **1400**, including a connector **1412** attached to the proximal end **1405** allowing the light diffusing device **1400** to be connected to a light source (not shown). As best shown in Figs. 14B, 14C, 14D the light diffusing device **1400** is made for reasons of economy as well as flexibility from a plastic optical fiber **10** approximately 1mm in diameter which comprises a light transmitting core fiber **1410** made of PMMA (acrylic) surrounded by cladding **1408** made of fluorinated polymers. It should be mentioned that other kinds of light transmitting fibers (not shown) could

also be used and are therefore contemplated by and within the scope of the invention. In this embodiment, the light diffusing device **1400** is also covered by sheathing **1418** which serves to further protect the device **1400**. The sheathing **1418** can be polymeric materials such as PTFE, polyester, polyurethane, PMMA, PEBAX or other suitable materials and can be applied by heat shrink, non-heat shrink techniques or adhesive techniques (i.e., epoxy and uv cured materials, among others). The core fiber **1410** and cladding **1408** have different indexes of refraction, which enables light entering the light diffusing device **1400** at the connector **1412** to be transmitted along the length of the light diffusing device **1400** and thereby transmitted to a more distal location. The light diffusing device **1400** defines a distal end **1406** to which is attached a piercing tip **1414**, preventing the escape of the transmitted light energy from an open distal end (not shown) of the core fiber **1410**. The piercing tip **1414** also allows the device **1400** to pierce or penetrate and thereby be implanted into tissue following the application of gentle force by the physician. In one embodiment, the piercing tip **1414** is made of machined (sharpened) stainless steel, however, this is not intended to be limiting as other metallic, composite and polymeric materials could also be used. Using appropriate medical grade adhesives, the piercing tip **1414** is attached to the distal end **1406** of the light diffusing device **1400** after the distal end **1406** is roughened by such means as sandpaper, sandblasting, chemical degradation or other abrasive or erosive methods.

The light emitting section **1402** is defined by an extended light port **1404** which is cut through the cladding **1408** exposing the core fiber **1400** allowing the transmitted light to be emitted from the light diffusing device **1400**. While a single extended light port **1404** is shown in Figs. 14-14D, this is for purposes of illustration only and the invention could also include multiple extended light ports **1404** (not shown). As best shown in Figs. 14B, 14C, 14D, the light emitting section **1402** is characterized by the light port **1404** extending progressively wider through the cladding **1408** as the distal end is reached. Restated, the progressively wider light port **1404** toward the distal end results in a lesser exposed core fiber **1410** surface area at the proximal end **1402b** of the light emitting section **1402** and a greater exposed core fiber **1410** surface area at the distal end **1402a** of the light emitting section **1402**, allowing a greater quantity of light to be available at the distal end **1402a** of the light emitting section **1402**. The reason for this is that if the width of the light port **1404**

was consistent (not shown), more light would be emitted from the proximal end **1402b** of the light port **1404**, leaving less light available to be emitted from the distal end **1402a** of the light port **1404**. The result of a uniform width light port **1404** (not shown) would be an optical fiber (not shown) having uneven light distribution, with more intensity toward the proximal end and less toward the distal end. The embodiment of the light diffusing device **1400** shown in Fig. 14 thus evenly emits the transmitted light energy along the length of the light emitting section **1402**, allowing safer and more precise photodynamic therapy.

Fig. 15 shows the light emitting section **1502** of an embodiment of a light diffusing device **1500** of the present invention. Fig. 15A shows the entire light diffusing device **1500**, including a connector **1512** attached to the proximal end **1505** allowing the light diffusing device **1500** to be connected to a light source (not shown). As best shown in Fig. 15B the light diffusing device **1500** is made for reasons of economy as well as flexibility from a plastic optical fiber **10** approximately 1mm in diameter which comprises a light transmitting core fiber **1510** made of PMMA (acrylic) surrounded by cladding **1508** made of fluorinated polymers. It should be mentioned that other kinds of light transmitting fibers (not shown) could also be used and are therefore contemplated by and within the scope of the invention. In this embodiment, the light diffusing device **1500** is also covered by sheathing **1518** which serves to further protect the device **1500**. The sheathing **1518** can be polymeric materials such as PTFE, polyester, polyurethane, PMMA, PEBAX or other suitable materials and can be applied by heat shrink, non-heat shrink techniques or adhesive techniques (i.e., epoxy and uv cured materials, among others). The core fiber **1510** and cladding **1508** have different indexes of refraction, which enables light entering the light diffusing device **1500** at a proximal location to be transmitted along the length of the light diffusing device **1500** and thereby transmitted to a more distal location. The light diffusing device **1500** defines a distal end **1506** which comprises a piercing tip **1514**, preventing the escape of the transmitted light energy from an open distal end (not shown) of the core fiber **1510**. The piercing tip **1514** also allows the device **1500** to pierce or penetrate tissue following the application of gentle force by the physician, allowing the device **1500** to be implanted into tissue. In one embodiment, the piercing tip **1514** is made of machined (sharpened) stainless steel, however, this is not intended to be limiting as other metallic, composite and

polymeric materials could also be used. In this embodiment a section of fluorescent material **1516** is attached to the distal end **1506** of the optical fiber **10** using appropriate medical grade adhesive before attaching the piercing tip **1514**. Using appropriate medical grade adhesives, the piercing tip **1514** is then attached to the distal end **1506** of the light diffusing device **1500** after the distal end (unnumbered) of the fluorescent material **1516** is roughened by such means as sandpaper, sandblasting, chemical degradation or other abrasive methods. The fluorescent material **1516** emits a signal when illuminated by light energy having a wavelength at least at an excitation wavelength and above and thus functions as a fluorescence feedback indicator. In this configuration, when the laser light source (not shown) is energized fluorescence occurs at the distal end **1506** and is detected at the light source console (not shown) to verify the light diffusing device **1500** is valid and functioning properly. In another embodiment (not shown) the end piece **1514** may be omitted and replaced by other light blocking mechanisms including opaque epoxy or plastic materials.

The light emitting section **1502** is defined by a plurality of light ports **1504** which extend through the cladding **1508** exposing core fiber **1510** allowing the transmitted light energy to be emitted from the light diffusing device **1500**. As best shown in Fig. 15, the light emitting section **1502** is characterized by the light ports **1504** progressively exposing a greater core fiber **1510** surface area as the distal end **1506** is reached. The light ports **1504** are conically shaped and spacing may vary in diameter between 0.003 inches to 0.006 inches. Restated, progressively greater sized light ports **1504** toward the distal end **1502a** result in a lesser exposed core fiber **1510** surface area at the proximal end **1502b** of the light emitting section **1502** and a greater exposed core fiber **1510** surface area at the distal end **1502a** of the light emitting section **1502**, allowing a greater quantity of light to be available at the distal end **1506** of the light emitting section **1502**. The reason for this is that if the surface area of the light ports **1504** was consistent (not shown), more light would be emitted from the more proximally located light ports **1504**, leaving less light available to be emitted from the more distally located light ports **1504**. The result of similarly sized light ports **1504** (not shown) would be an optical fiber (not shown) having uneven light distribution, with more intensity toward the proximal end and less toward the distal end. The embodiment of the light diffusing device **1500** shown in Figs. 15-15B thus

evenly emits the transmitted light energy along the length of the light emitting section **1502**, allowing safer and more precise photodynamic therapy.

Fig. 16 shows the light emitting section **1602** of an embodiment of a light diffusing device **1600** of the present invention. Fig. 16A shows the entire light diffusing device **1600**, including a connector **1612** attached to the proximal end **1605** allowing the light diffusing device **1600** to be connected to a light source (not shown). As best shown in Figs. 16B, 16C, 16D the light diffusing device **1600** is made for reasons of economy as well as flexibility from a plastic optical fiber **10** approximately 1mm in diameter which comprises a light transmitting core fiber **1610** made of PMMA (acrylic) surrounded by cladding **1608** made of fluorinated polymers. It should be mentioned that other kinds of light transmitting fibers (not shown) could also be used and are therefore contemplated by and within the scope of the invention. In this embodiment, the light diffusing device **1600** is also covered by sheathing **1618** which serves to further strengthen and protect the device **1600**. The sheathing **1618** can be polymeric materials such as PTFE, polyester, polyurethane, PMMA, PEBAX or other suitable materials and can be applied by heat shrink, non-heat shrink techniques or adhesive techniques (i.e., epoxy and uv cured materials, among others). The core fiber **1610** and cladding **1608** have different indexes of refraction, which enables light entering the light diffusing device **1600** at the connector **1612** to be transmitted along the length of the light diffusing device **1600** and thereby transmitted to a more distal location. The optical fiber **10** defines a distal end **1606** to which a section of fluorescent material **1616** is attached using appropriate medical grade adhesive. The fluorescent material **1616** emits a signal when illuminated by light energy having a wavelength at least at an excitation wavelength and above and thus functions as a fluorescence feedback indicator. In this configuration, when the laser light source (not shown) is energized fluorescence occurs at the distal end **1606** and is detected at the light source console (not shown) to verify the light diffusing device **1600** is valid and functioning properly. In this embodiment, the piercing tip of other embodiments is replaced by encapsulating the fluorescent material **1616** with sheathing **1618** which is hardened and sharpened to form a piercing distal end **1614**. This allows the device **1600** to pierce or penetrate tissue upon the application of gentle force by the physician.

The light emitting section **1602** is defined by a plurality of light ports **1604** which extend through the cladding **1608** into the core fiber **1600** allowing the transmitted light to be emitted from the light diffusing device **1600**. As best shown in Figs. 16B, 16C, 16D, the light emitting section **1602** is characterized by the light ports **1604** having a similar surface area that extend progressively deeper into the core fiber **1610** as the distal end **1602a** is reached. The light ports **1604** are conically shaped and the depth may vary between 0.004 inches to 0.008 inches. Restated, progressively deeper, similarly sized light ports **1604** toward the distal end **1602a** result in a lesser exposed core fiber **1610** surface area at the proximal end **1602b** of the light emitting section **1602** and a greater exposed core fiber **1610** surface area at the distal end **1602a** of the light emitting section **1602**, allowing a greater quantity of light to be available at the distal end **1602a** of the light emitting section **1602**. The reason for this is that if the size and depth of light ports **1604** was consistent (not shown), more light would be emitted from the more proximally located light ports **1604**, leaving less light available to be emitted from the more distally located light ports **1604**. The result of similarly sized and depth light ports **1604** (not shown) would be an optical fiber (not shown) having uneven light distribution, with more intensity toward the proximal end and less toward the distal end. The embodiment of the light diffusing device **1600** shown in Fig. 16 thus evenly emits the transmitted light energy along the length of the light emitting section **1602**, allowing safer and more precise photodynamic therapy.

Fig. 17 shows the light emitting section **1702** of an embodiment of the light diffusing device **1700** of the present invention. A plan view of the light emitting section as shown in Fig. 17A shows the entire light diffusing device **1700**, including a connector **1712** attached to the proximal end **1705** allowing the light diffusing device **1700** to be connected to a light source (not shown). As best shown in Fig. 17B the light diffusing device **1700** is made for reasons of economy as well as flexibility from a plastic optical fiber **10** approximately 1mm in diameter which comprises a light transmitting core fiber **1710** made of PMMA (acrylic) surrounded by cladding **1708** made of fluorinated polymers. It should be mentioned that other kinds of light transmitting fibers (not shown) could also be used and are therefore contemplated by and within the scope of the invention. The core fiber **1710** and cladding **1708** have different indexes of refraction, which enables light entering the light diffusing device

1700 at the connector **1712** to be transmitted along the length of the light diffusing device **1700** and thereby transmitted to a more distal location. The light diffusing device **1700** defines a distal end **1706** to which is attached an opaque end piece **1714**, preventing the escape of the transmitted light energy from an open distal end (not shown) of the core fiber **1710**. In one embodiment, the end piece **1714** is made of stainless steel. Using appropriate medical grade adhesives, the end piece **1714** is attached to the distal end **1706** of the light diffusing device **1700** after the distal end **1706** is roughened by such means as sandpaper, sandblasting, chemical degradation or other abrasive methods. In another embodiment (not shown) the end piece **1714** may be omitted and replaced by other light blocking mechanisms including opaque epoxy or plastic materials. In an alternative embodiment (not shown) the light diffusing device **1700** may be encased in a transparent protective sheath (not shown) which provides an additional degree of integrity as well as smoothness.

In this embodiment the light diffusing device **1700** the cladding **1708** is not removed. The light emitting section **1702** is defined by progressively distally roughening the surface of the cladding **1708** defining the light emitting section **1702** allowing an increased amount of transmitted light to be emitted from the light diffusing device **1700**. As best shown in Fig.17 the light emitting section **1702** is characterized by the light emitting section **1702** having a relatively smooth area **1704b** which becomes progressively rougher **1704a** along the core fiber **1710** as the distal end **1702a** is reached. Restated, the progressively rougher light emitting section **1702** toward the distal end **1702a** results in a lesser exposed core fiber **1710** surface area at the proximal end **1702b** of the light emitting section **1702** and a greater exposed core fiber **1710** surface area at the distal end **1702a** of the light emitting section **1702**, allowing a greater quantity of light to be available at the distal end (unnumbered) of the light emitting section **1702**. The reason for this is that if the roughness of the light emitting section **1702** was consistent (not shown), more light would be emitted from the proximal end of the light emitting section **1702**, leaving less light available to be emitted from the distal end of the light emitting section **1702**. The result of a uniform roughness light emitting section **1702** (not shown) would be a light diffusing device (not shown) having uneven light distribution, with more intensity toward the proximal end and less toward the distal end. The embodiment of the light diffusing device **1700** shown in Fig. 17 thus evenly emits the transmitted

light energy along the length of the light emitting section **1702**, allowing safer and more precise photodynamic therapy.

The light ports **104, 204, 304, 404, 504, 1204, 1304, 1404, 1504, 1604** and removed core fiber sections **604, 704, 804, 904, 1004** are created by securing a virgin plastic optical fiber (not shown) in a fixture (not shown) and then energizing a CO_2 laser (not shown) focused in the appropriate location(s). In one embodiment the fixture (not shown) is translated only on the X axis which moves longitudinally and rotates in order to create the light ports **104, 304, 404, 1204, 1304, 1404, 1504, 1604** and removed core fiber sections **604, 704, 804, 904, 1004**. In embodiments **200, 500, 1400, 1500, 1600** which have a wider light port **204, 504, 1404, 1504, 1604**, removed core fiber section **900** or deeper light port **300, 400**, is required, the fixture (not shown) may additionally translate in the Y axis, moving the CO_2 laser closer to the virgin optical fiber (not shown). In another embodiment, repositioning of the optical fiber (not shown) in the fixture (not shown) may be required to allow for the creation of light ports **104, 204, 304, 404, 504, 1104, 1204, 1304, 1404, 1504, 1604** or removed core fiber sections **604, 704, 804, 904, 1004** that would be covered by the mandrel during an earlier laser drilling treatment. When energized, the laser pulse of the CO_2 laser (not shown) may have a 10.6 micron wavelength at 5 watts with a pulse duration between approximately 0.0003 to 0.0010 seconds. This results in controlled removal of the cladding **108, 208, 308, 408, 508, 1104, 1204, 1304, 1404, 1504, 1604** and in some cases part of the core fiber **110, 210, 310, 410, 510, 610, 710, 810, 910, 1010, 1110, 1210, 1310, 1410, 1510, 1610** without unduly damaging the core fiber **110, 210, 310, 410, 510, 610, 710, 810, 910, 1010, 1110, 1210, 1310, 1410, 1510, 1610**. In the case of the embodiment of the light diffusing device **1100** the cladding is first removed from the section of the optical fiber **10** desired to become the light emitting section **1102**, in the embodiment as shown, toward the distal end of the light diffusing device **1100**. The embodiment of the light diffusing device **1700** does not require removal of any cladding **1708**. Next, the light emitting section **1102, 1702** is treated with abrasives such as sandpaper, sand blasting or other abrasive techniques, starting at the proximal end **1102b, 1702b** of the light emitting section **1102, 1702** and progressing for a longer period in a distal direction until the distal end **1102a, 1702a** is reached. This results in a light emitting section **1102, 1702** which is progressively rougher in a distal direction.

Use

Using the light diffusing device **100, 200, 300, 400, 500, 600, 700, 800, 900, 1000, 1100, 1200, 1300, 1400, 1500, 1600, 1700** of the present invention involves initially treating the patient at the treatment site with a photosensitizing agent such as methylene blue or another of many photosensitizing agents well known in the art. Depending on the nature of the photodynamic therapy treatment, a period of time may be required to allow for absorption of the particular photosensitizing agent into the affected tissue. The light diffusing device **100, 200, 300, 400, 500, 600, 700, 800, 900, 1000, 1100, 1200, 1300, 1400, 1500, 1600, 1700** is removed from sterile packaging followed by positioning it in the treatment area. In the embodiments **1200, 1300, 1400, 1500, 1600** configured to be tissue piercing or penetrating, gentle pressure is applied to the device **1200, 1300, 1400, 1500, 1600** by the physician, causing it to become implanted into the intended tissue requiring treatment. Via the connector **112, 212, 312, 412, 512, 612, 712, 812, 912, 1012, 1112, 1212, 1312, 1412, 1512, 1612, 1712** the light diffusing device **100, 200, 300, 400, 500, 600, 700, 800, 900, 1000, 1100, 1200, 1300, 1400, 1500, 1600, 1700** is connected to a light source (not shown) capable of producing light in the appropriate wavelength which varies with the particular photosensitizing agent used and treatment prescribed, followed by energizing the light source at the beginning of treatment. The light source is then energized for the prescribed length of time and intensity (which also varies with the particular photosensitizing agent used) then de-energized at the conclusion. Following the conclusion of treatment, the light diffusing device **100, 200, 300, 400, 500, 600, 700, 800, 900, 1000, 1100, 1200, 1300, 1400, 1500, 1600, 1700** is disposed of.

CLAIMS

What is claimed is:

1. A light diffusing device, comprising: an optical fiber defining a longitudinal dimension, a lateral dimension, a proximal end, a distal end wherein:

a) the optical fiber includes

(i) a core fiber; and

(ii) a cladding that covers at least one portion of the core fiber and has a different index of refraction than the core fiber, which enables light entering the proximate end of the optical fiber to transmit along length of the optical fiber toward the distal end of the optical fiber;

b) the optical fiber includes a light emitting section and at least one non-light emitting section;

c) the light emitting section is located outside the distal end of the optical fiber and includes a proximate end and a distal end;

d) the light emitting section is defined by at least one removed core fiber section;

e) a portion of the cladding and a portion of the core fiber located beneath the portion of the cladding are removed to form each of the at least one removed core fiber section and the removal of the portion of the core fiber increases surface area of the core fiber;

f) the at least one removed core fiber section exposes a progressively increasing amount of the surface area of the core fiber in a distal direction within the light emitting section, resulting in a desired distribution of the light emitted from the light emitting section.

2. The light diffusing device of claim 1 wherein the optical fiber is a plastic optical fiber.

3. The light diffusing device of claim 1 wherein the light emitting section is proximate the distal end of the optical fiber.

4. The light diffusing device of claim 1 further comprising an end piece attached to the distal end of the optical fiber wherein the end piece prevents the light from

emitting from the distal end of the optical fiber.

5. The light diffusing device of claim 4 the end piece is a piercing tip capable of penetrating tissue.

6. The light diffusing device of claim 4 further comprising fluorescent material between the end piece and the distal end of the optical fiber, wherein when light having at least an excitation frequency is transmitted to the fluorescent material through the optical fiber a light energy signal is generated indicating the light diffusing device is valid.

7. The light diffusing device of claim 1 wherein the at least one removed core fiber section is comprised of a plurality of similarly sized removed core fiber sections and having a distally increasing density, resulting in greater number of removed core fiber sections at the distal end of the light emitting section and lesser number of removed core fiber sections at the proximal end of the light emitting section.

8. The light diffusing device of claim 7 wherein spacing between each of the plurality of similarly sized removed core fiber sections ranges between 0.022 inches to 0.040 inches.

9. The light diffusing device of claim 1 wherein the at least one removed core fiber section is comprised of a plurality of removed core fiber sections having a distally increasing diameter, resulting in greater exposed core fiber surface area at the distal end of the light emitting section and lesser exposed core fiber surface area at the proximal end of the light emitting section.

10. The light diffusing device of claim 9 wherein the diameter of each of the plurality of removed core fiber sections ranges from 0.003 inches to 0.006 inches.

11. The light diffusing device of claim 1 wherein the at least one removed core fiber section is comprised of a plurality of similarly sized removed core fiber sections having a distally increasing depth into the core fiber, resulting in greater exposed core fiber

surface area at the distal end of the light emitting section and lesser exposed core fiber surface area at the proximal end of the light emitting section.

12. The light diffusing device of claim 11 wherein the depth of each of the plurality of removed core fiber sections ranges between 0.004 inches to 0.008 inches.

13. The light diffusing device of claim 1 wherein the at least one removed core fiber section is comprised of an extended removed core fiber section having a distally increasing depth into the core fiber, resulting in greater exposed core fiber surface area at the distal end of the light emitting section and lesser exposed core fiber surface area at the proximal end of the light emitting section.

14. The light diffusing device of claim 1 wherein the at least one removed core fiber section is comprised of an extended removed core fiber section having a distally increasing width, resulting in greater exposed core fiber surface area at the distal end of the light emitting section and lesser exposed core fiber surface area at the proximal end of the light emitting section.

15. The light diffusing device of claim 1 wherein the cladding within the light emitting section is completely removed.

16. The light diffusing device of claim 1 wherein at least a portion of the light diffusing device is covered by a sheath.

17. The light diffusing device of claim 1 wherein each of the at least one removed core fiber section is conically shaped.

18. A light diffusing device, comprising: an optical fiber defining a length, a diameter, a proximal end and a distal end and a core fiber at least partially covered by a cladding wherein a light emitting section is formed by selectively removing a portion of the cladding and a portion of the core fiber located beneath the removed portion of the cladding to form at least a single light port, such that a progressively distally increasing surface area of core fiber is exposed, resulting in an even distribution of light emitted from the light emitting section, the light emitting section further defining a distal end

and a proximal end.

19. The light diffusing device of claim 18 wherein an end piece is attached to the distal end of the optical fiber wherein the end piece prevents the light from emitting from the distal end of the optical fiber.

20. The light diffusing device of claim 19 wherein the end piece is a piercing tip capable of penetrating tissue.

21. The light diffusing device of claim 19 further comprising fluorescent material attached to between the end piece and the distal end of the optical fiber, wherein the fluorescent material fluoresces when exposed to light having a wavelength at least at an excitation wavelength.

22. The light diffusing device of claim 18 wherein the optical fiber is a plastic optical fiber.

23. The light diffusing device of claim 22 wherein the at least a single light port is comprised of a plurality of similarly sized light ports having a distally increasing density, resulting in a greater number of light ports at the distal end of the light emitting section and a lesser number of light ports at the proximal end of the light emitting section.

24. The light diffusing device of claim 23 wherein spacing between each of the plurality of similarly sized light ports ranges between 0.022 inches to 0.040 inches.

25. The light diffusing device of claim 22 wherein the at least a single light port is comprised of a plurality of light ports having a distally increasing diameter, resulting in a greater exposed core fiber surface area at the distal end of the light emitting section and a lesser exposed core fiber surface area at the proximal end of the light emitting section.

26. The light diffusing device of claim 25 wherein the diameter of each of the plurality of the light ports ranges from 0.003 inches to 0.006 inches.

27. The light diffusing device of claim 22 wherein the at least a single light port is comprised of a plurality of similarly sized light ports having a distally increasing depth, resulting in a greater exposed core fiber surface area at the distal end of the light emitting section and a lesser exposed core fiber surface area at the proximal end of the light emitting section.

28. The light diffusing device of claim 27 wherein the depth of each of the plurality of similarly sized light ports ranges between 0.004 inches to 0.008 inches.

29. The light diffusing device of claim 22 wherein the at least a single light port is comprised of an extended light port having a distally increasing depth, resulting in a greater exposed core fiber surface area at the distal end of the light emitting section and a lesser exposed core fiber surface area at the proximal end of the light emitting section.

30. The light diffusing device of claim 22 wherein the at least a single light port is comprised of an extended light port having a distally increasing width, resulting in a greater exposed core fiber surface area at the distal end of the light emitting section and a lesser exposed core fiber surface area at the proximal end of the light emitting section.

31. The light diffusing device of claim 22 wherein the cladding within the light emitting section is completely removed.

32. The light diffusing device of claim 18 wherein at least a portion of the diffusing device is covered by a sheath.

33. The light diffusing device of claim 18 wherein each of the at least a single light port is conically shaped.

34. A light diffusing device, comprising:

an optical fiber defining a longitudinal dimension, a lateral dimension, a proximal end, a distal end; and

an end piece that is attached to the distal end of the optical fiber, wherein:

a) the optical fiber includes

(i) a core fiber; and

(ii) a cladding that covers at least one portion of the core fiber and has a different index of refraction than the core fiber, which enables light entering the proximate end of the optical fiber to transmit along length of the optical fiber toward the distal end of the optical fiber;

b) the end piece prevents the light from emitting from the distal end of the optical fiber.

c) the optical fiber includes a light emitting section and at least one non-light emitting section;

d) the light emitting section is located outside the distal end of the optical fiber and includes a proximate end and a distal end;

e) the cladding is completely removed from the light emitting section;

f) the light emitting section is defined by at least one removed core fiber section;

g) a portion of the core fiber is removed in each of the at least one removed core fiber section and the removal of the portion of the core fiber increases surface area of the core fiber;

h) the at least one removed core fiber section exposes a progressively increasing amount of the surface area of the core fiber in a distal direction within the light emitting section, resulting in a desired distribution of the light emitted from the light emitting section; and

i) a laser is used to create the at least one removed core fiber section.

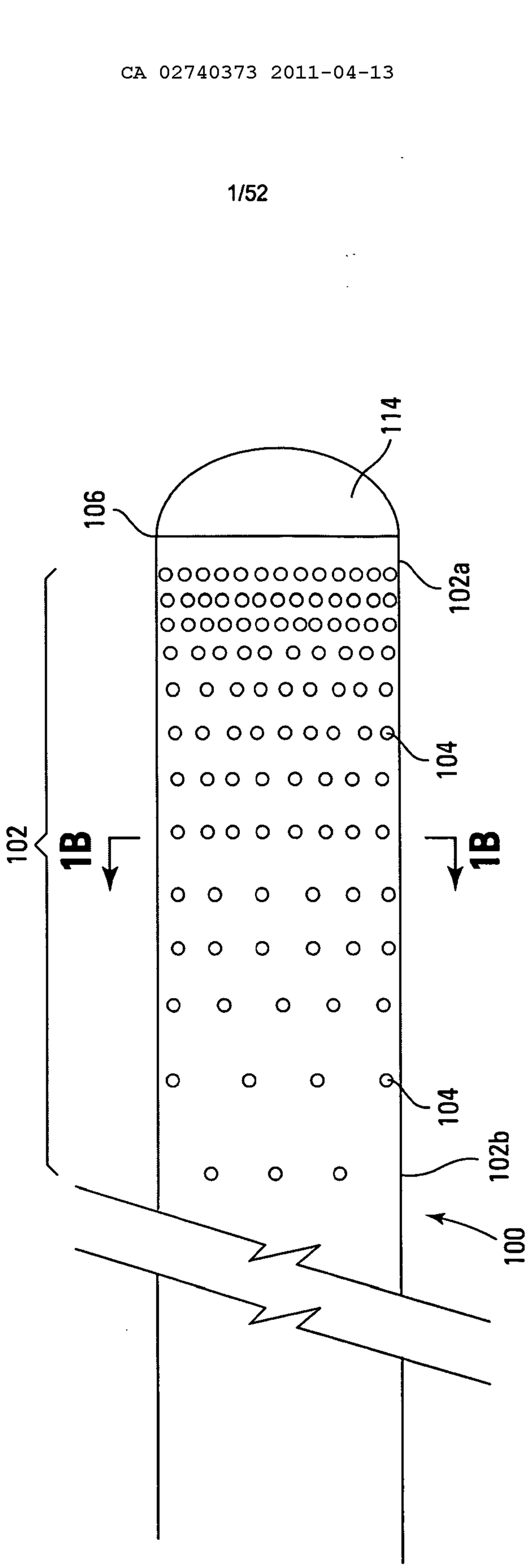


FIG. 1

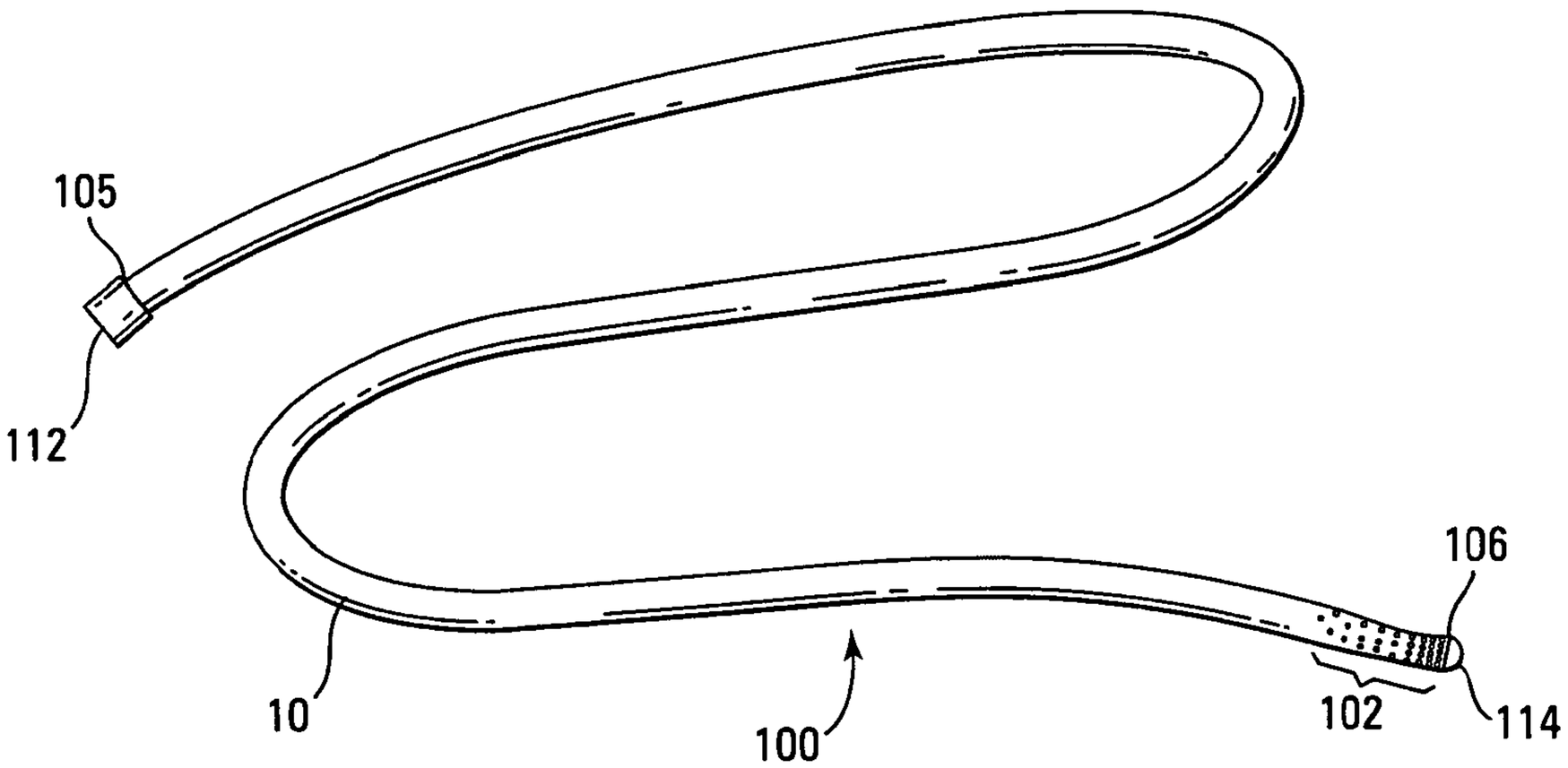


FIG. 1A

FIG. 1B

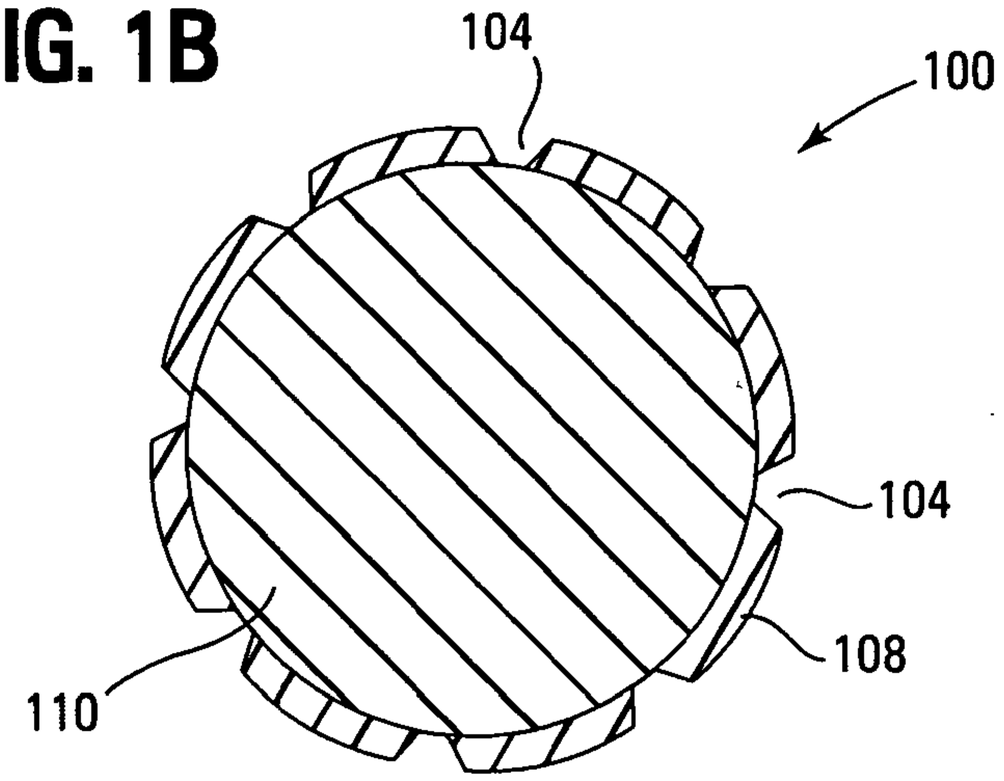
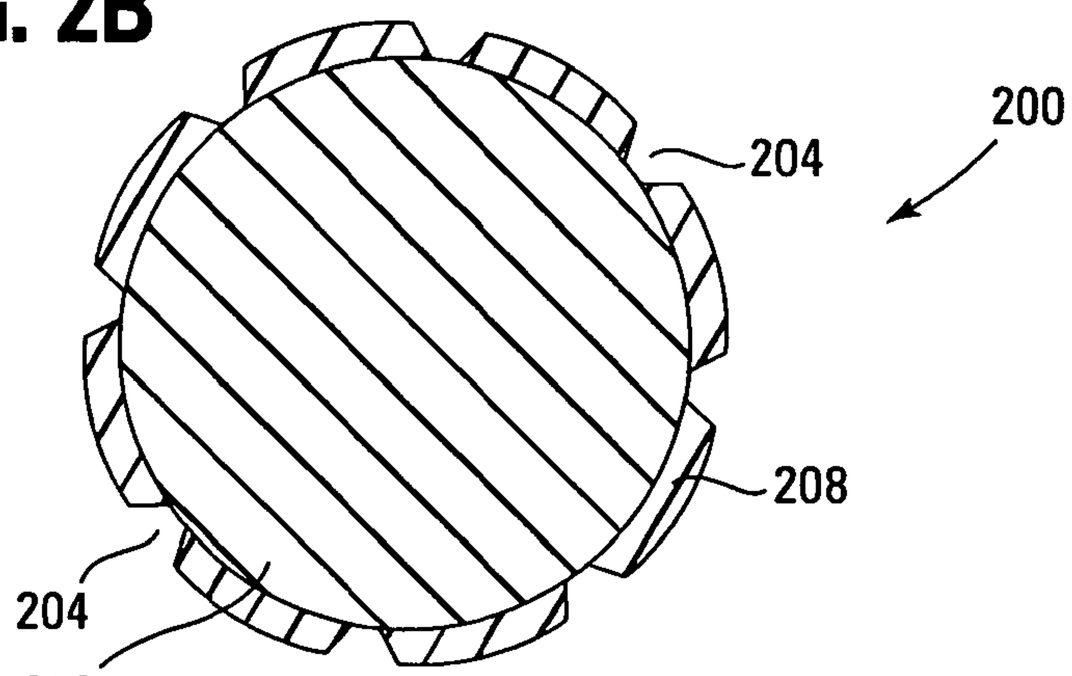


FIG. 2B



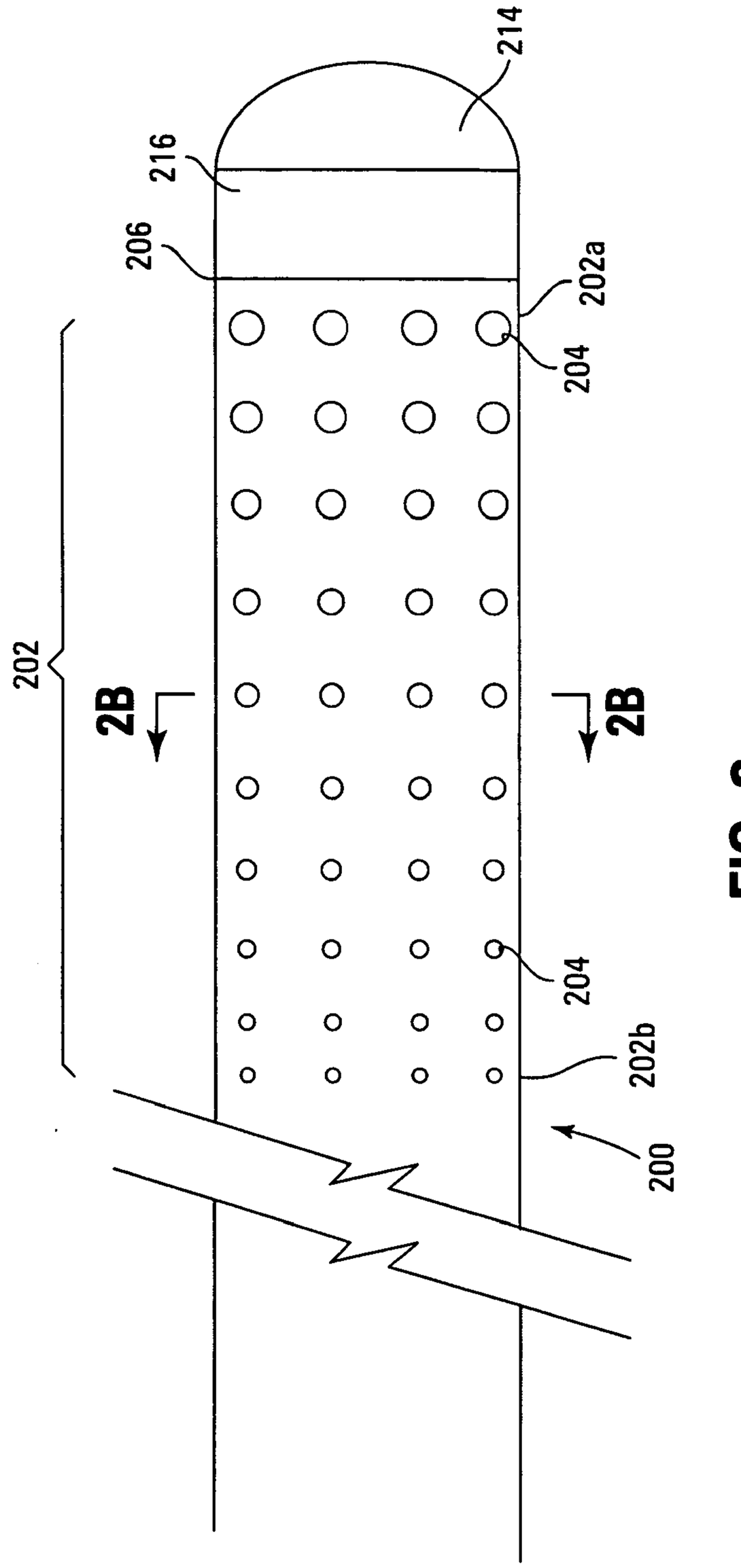


FIG. 2

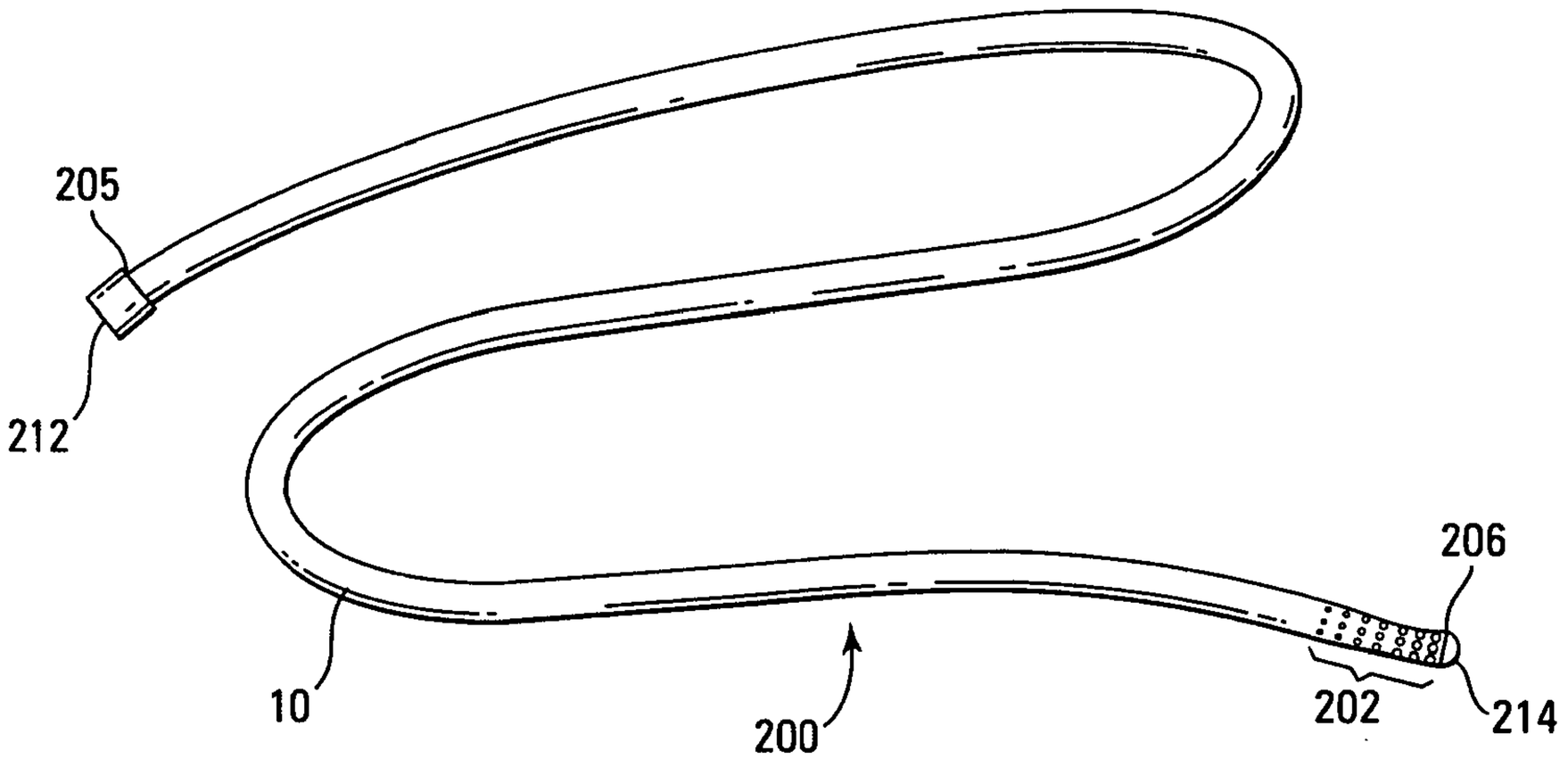


FIG. 2A

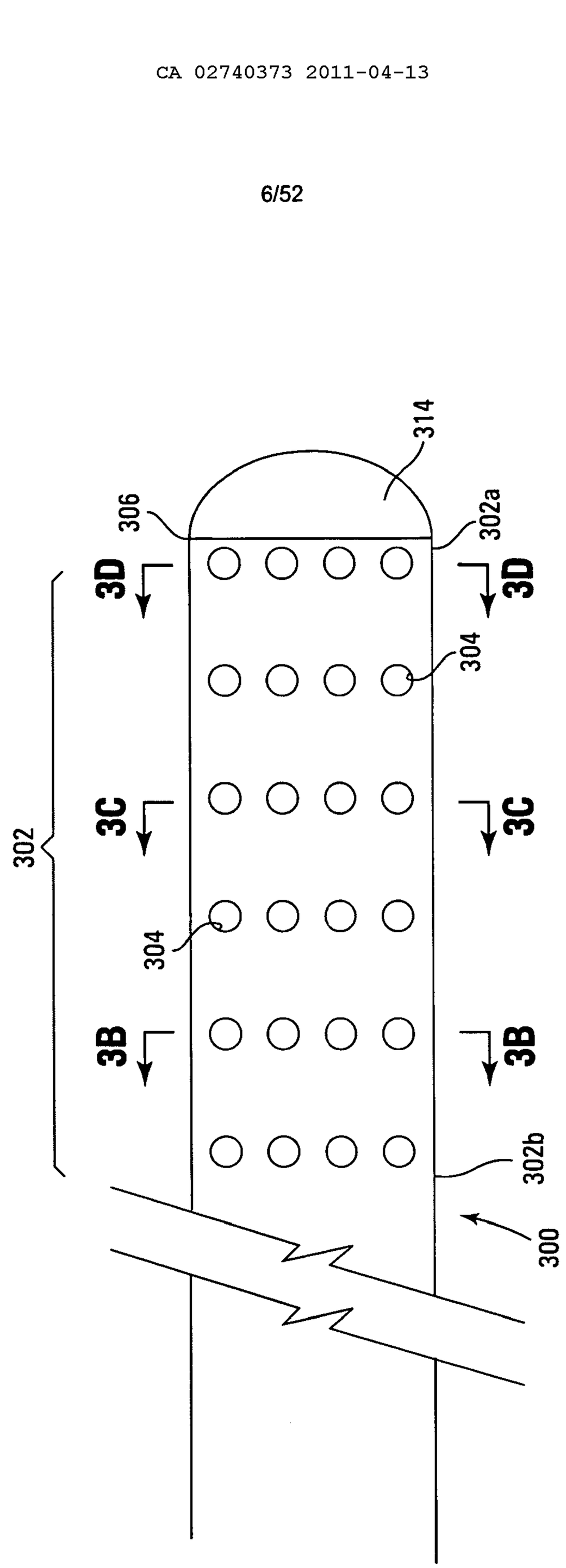


FIG. 3

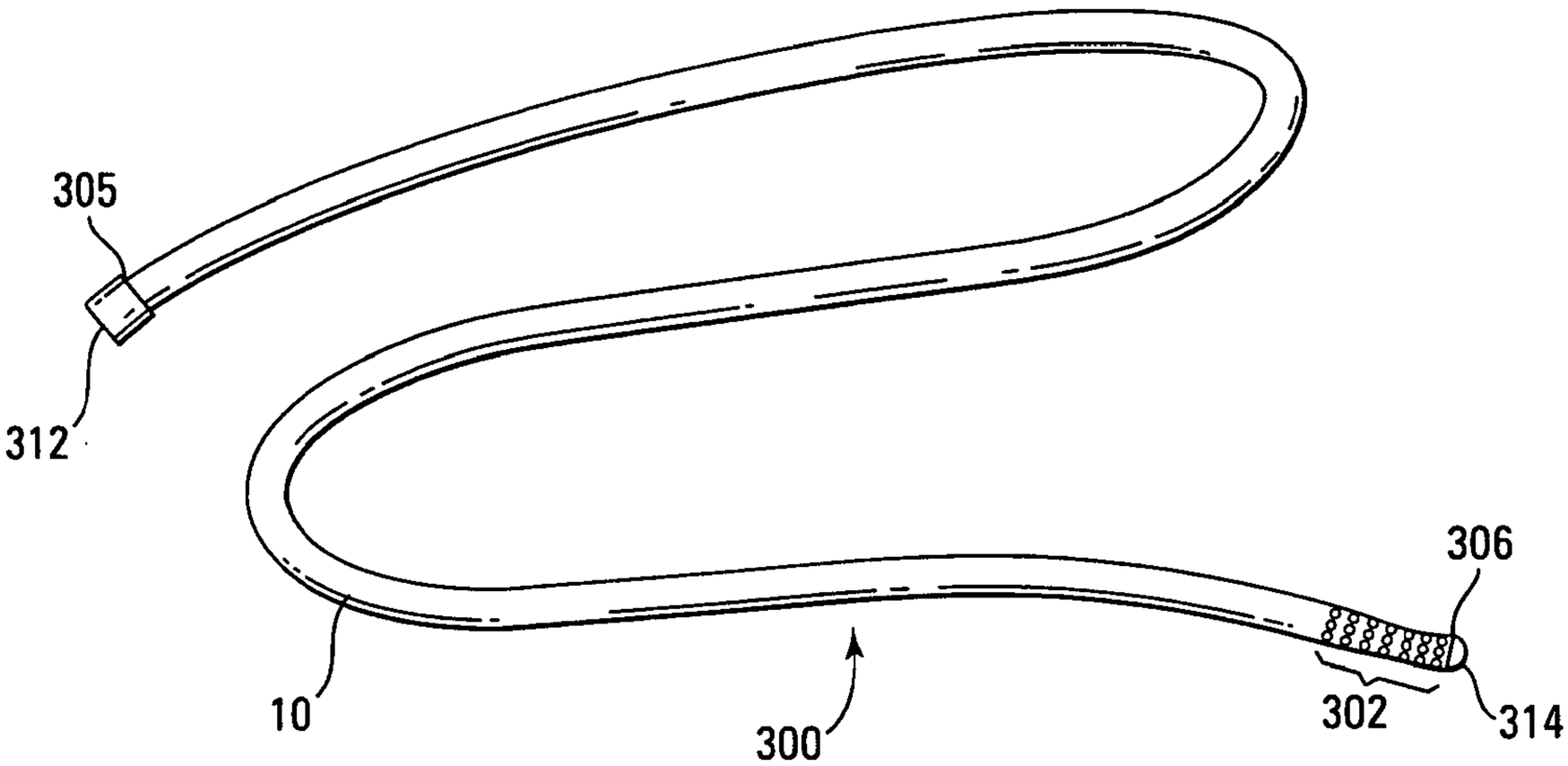


FIG. 3A

FIG. 3B

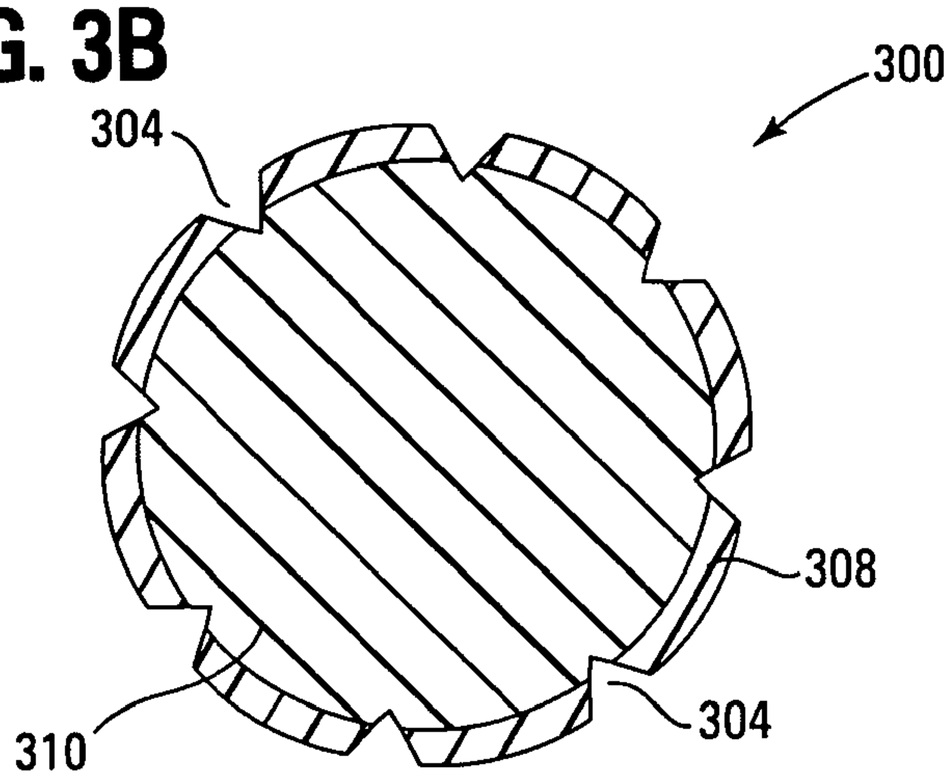


FIG. 3C

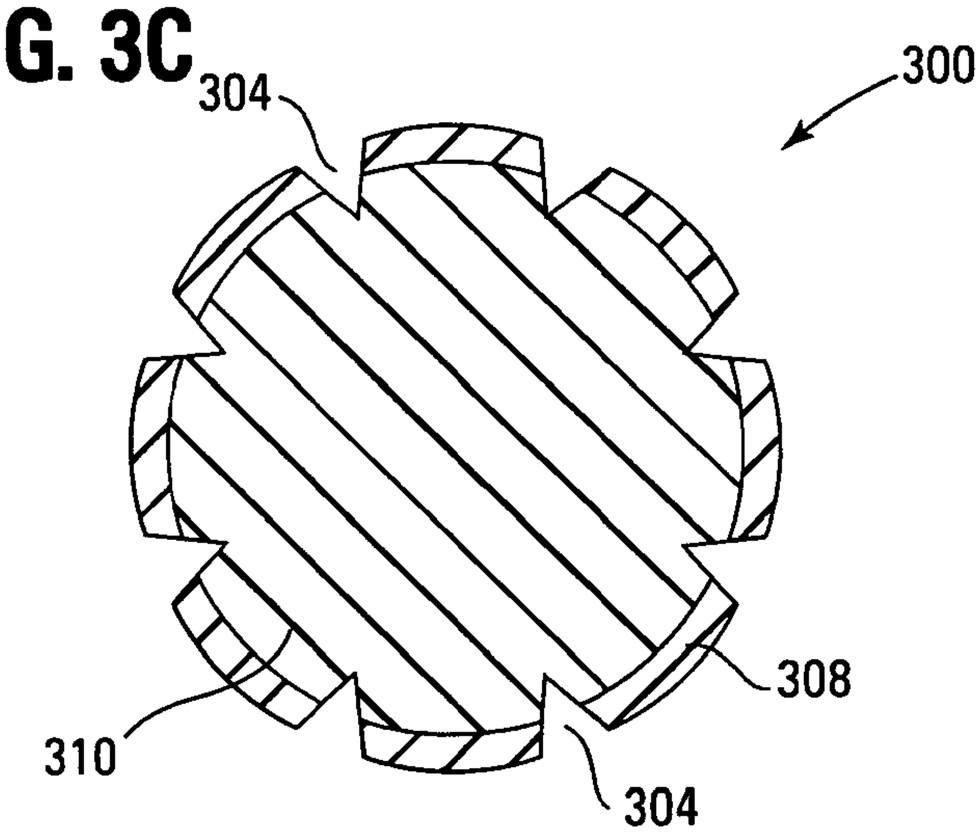
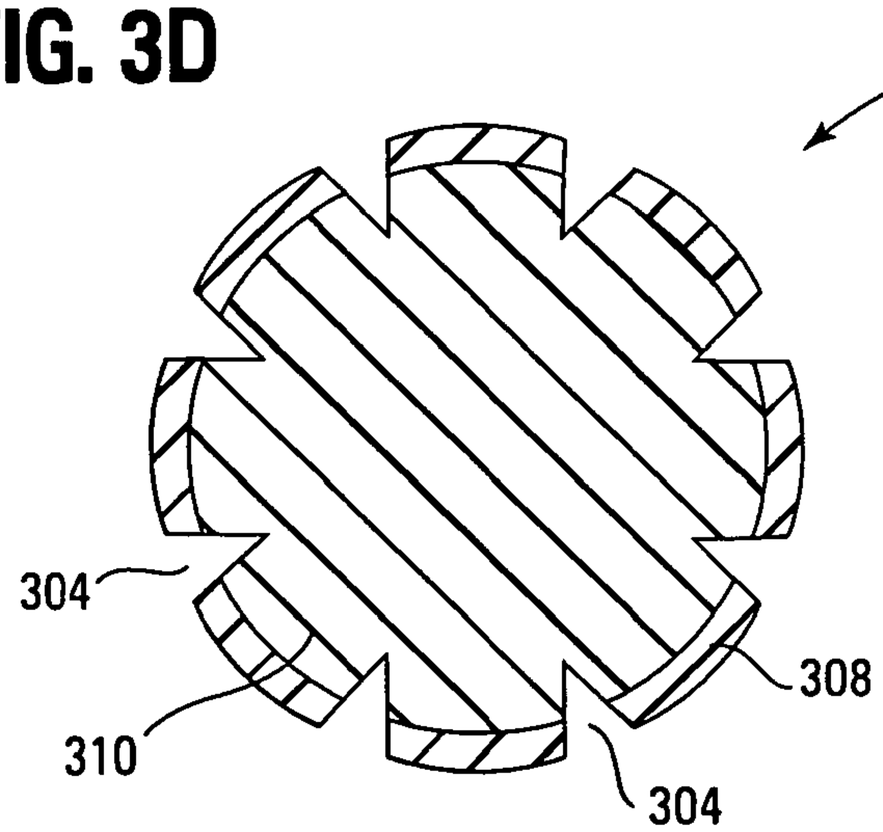


FIG. 3D



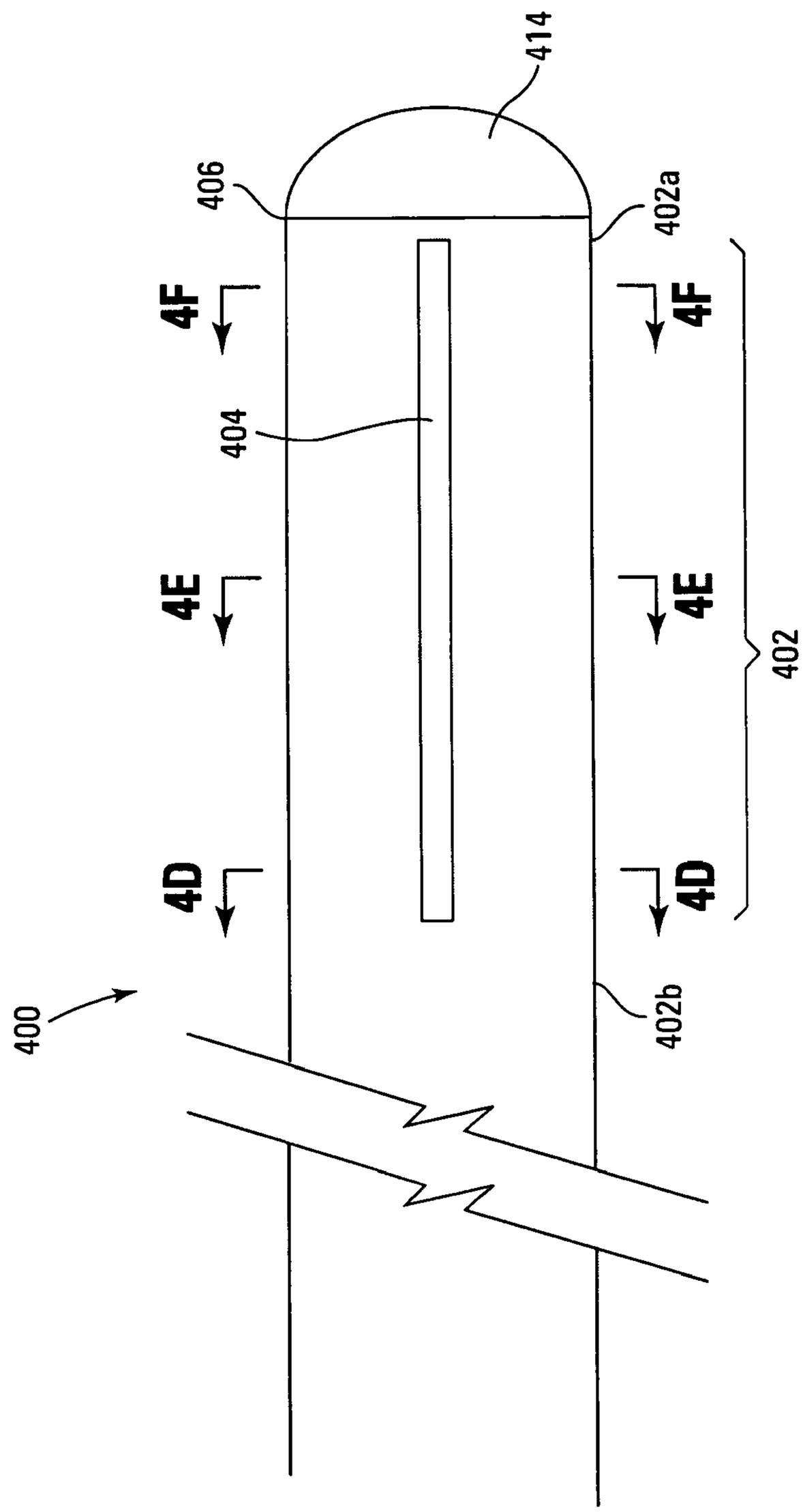


FIG. 4A

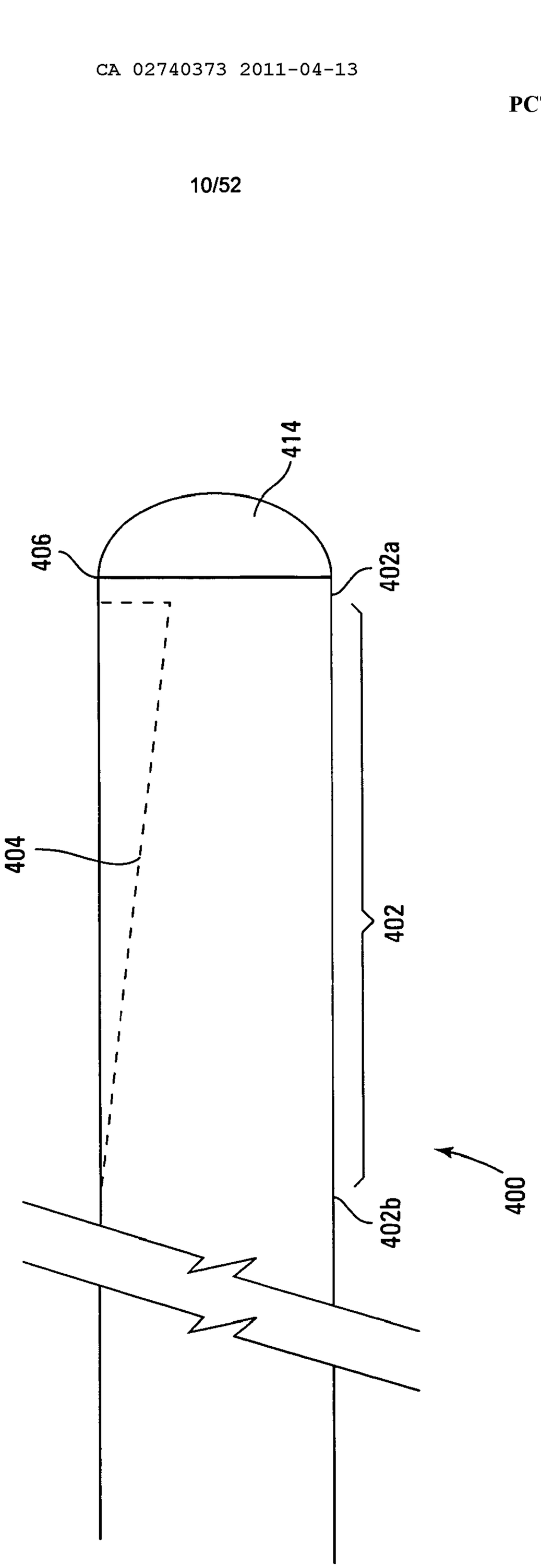


FIG. 4B

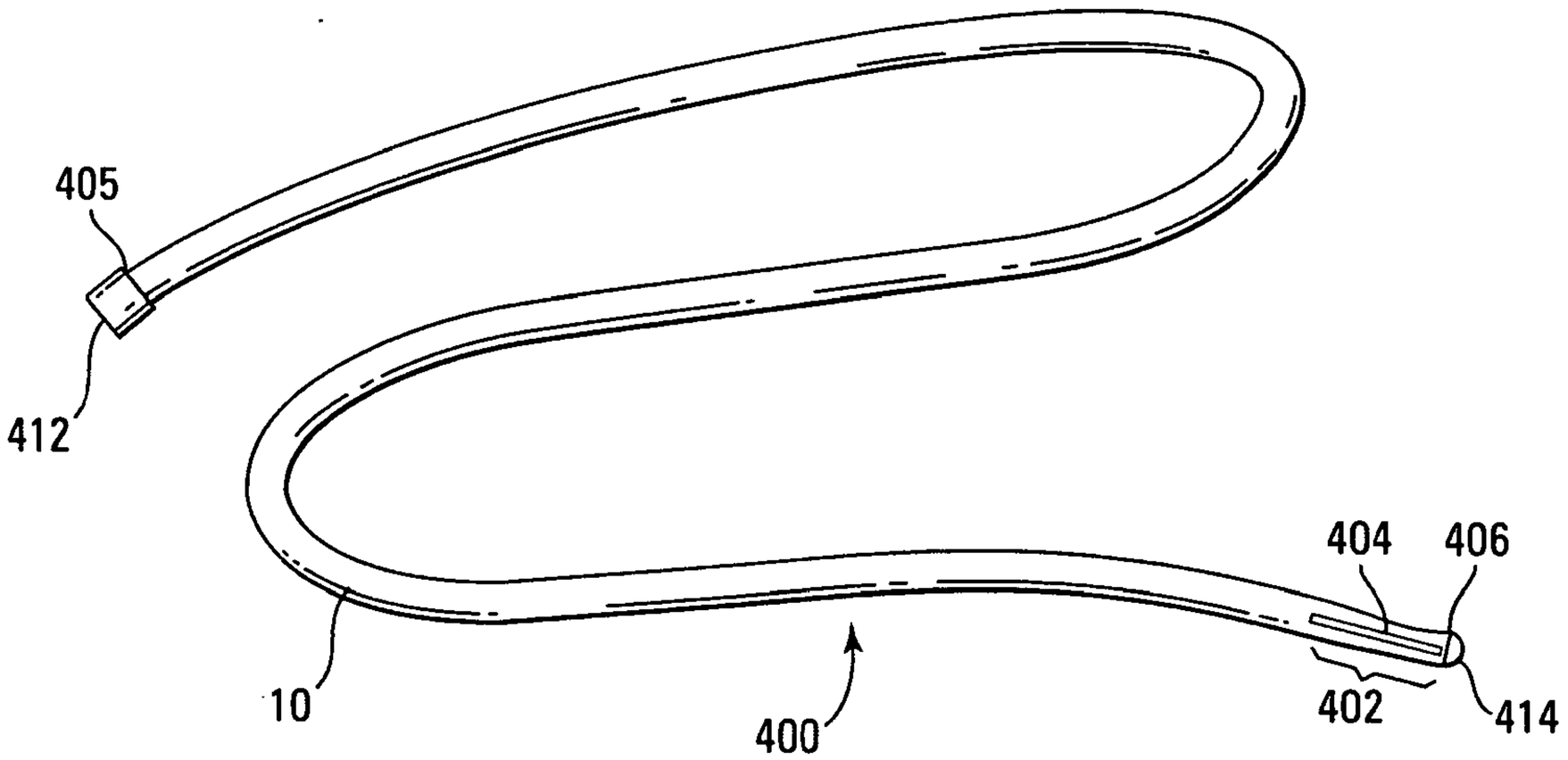


FIG. 4C

FIG. 4D

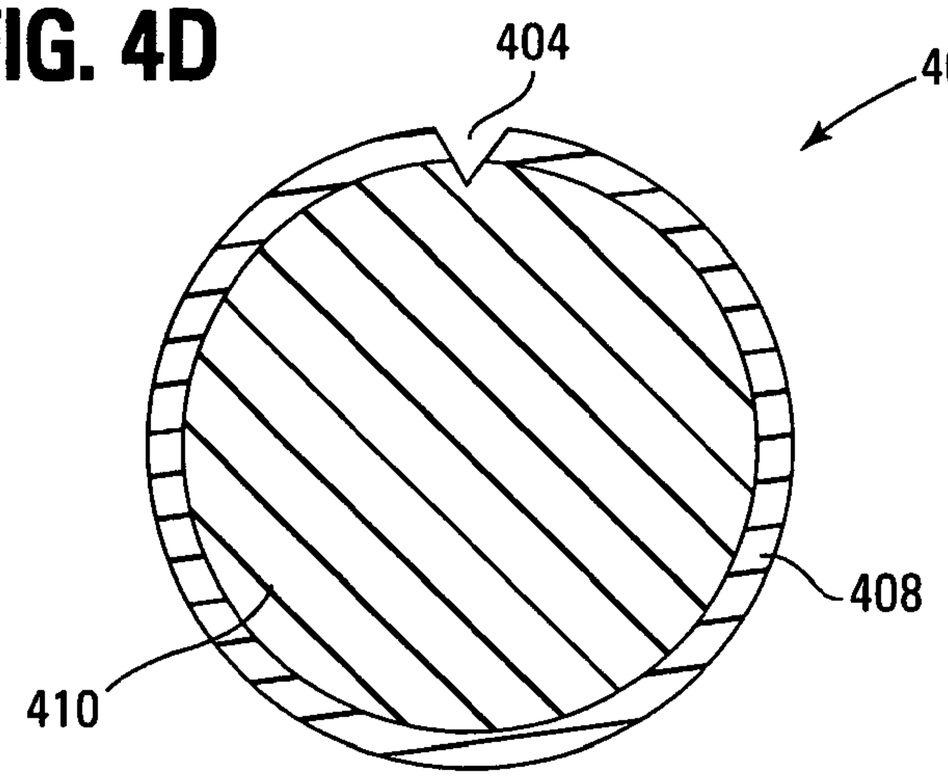


FIG. 4E

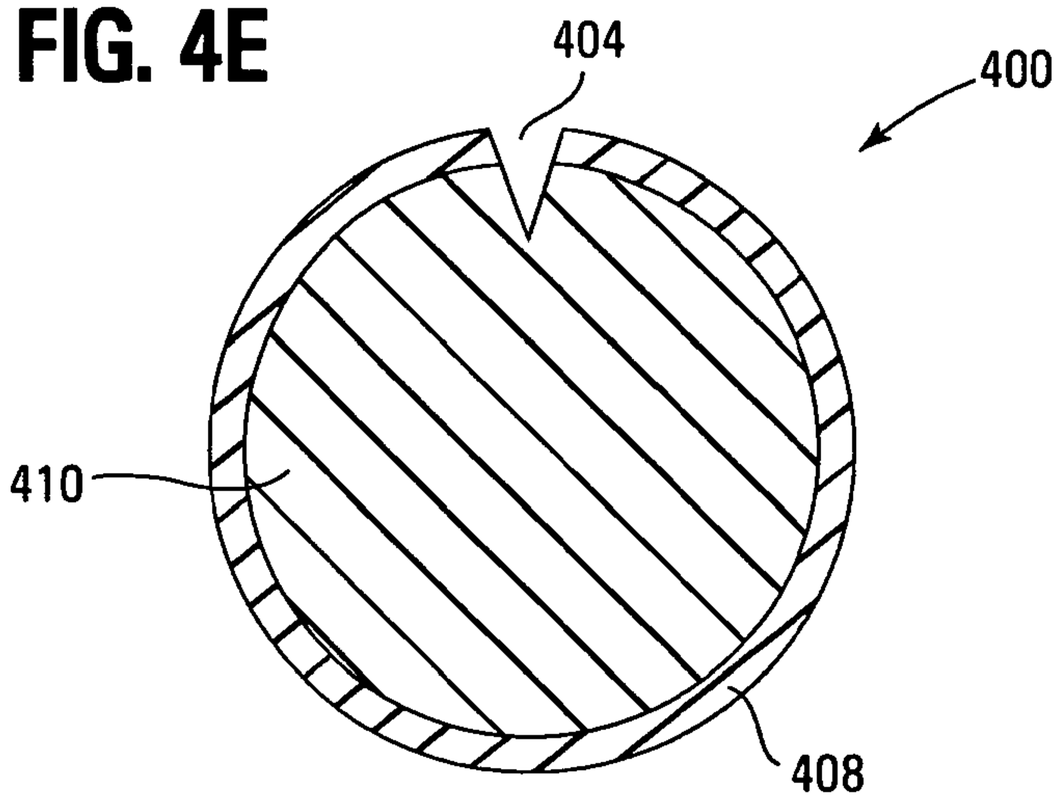
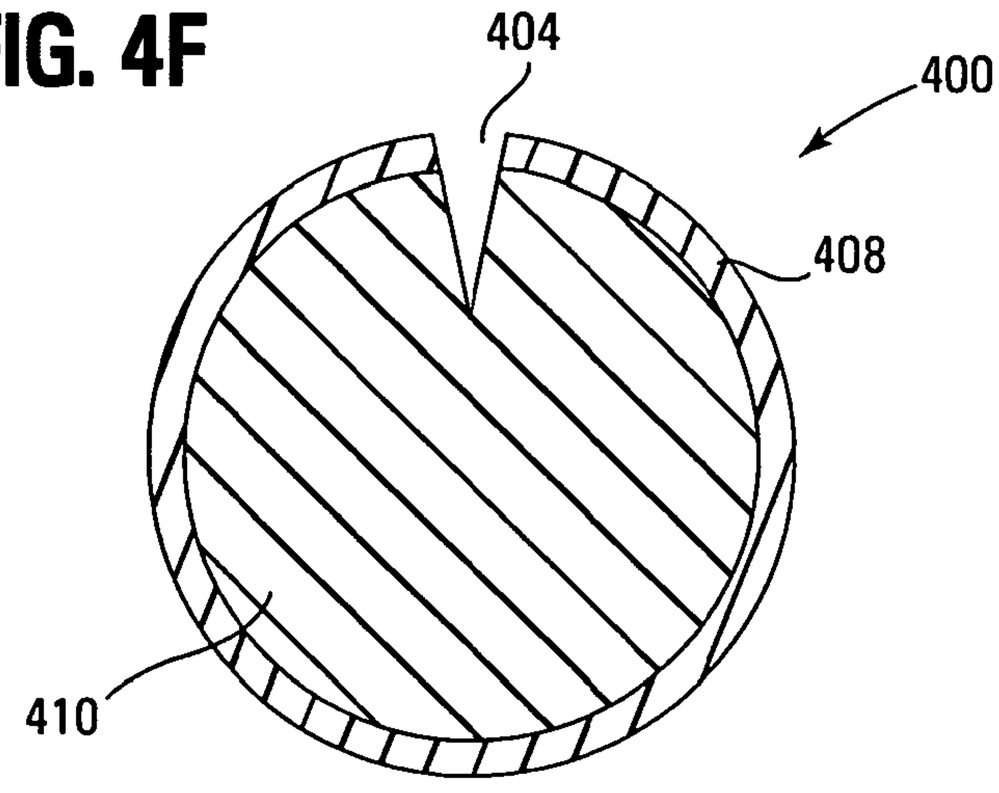


FIG. 4F



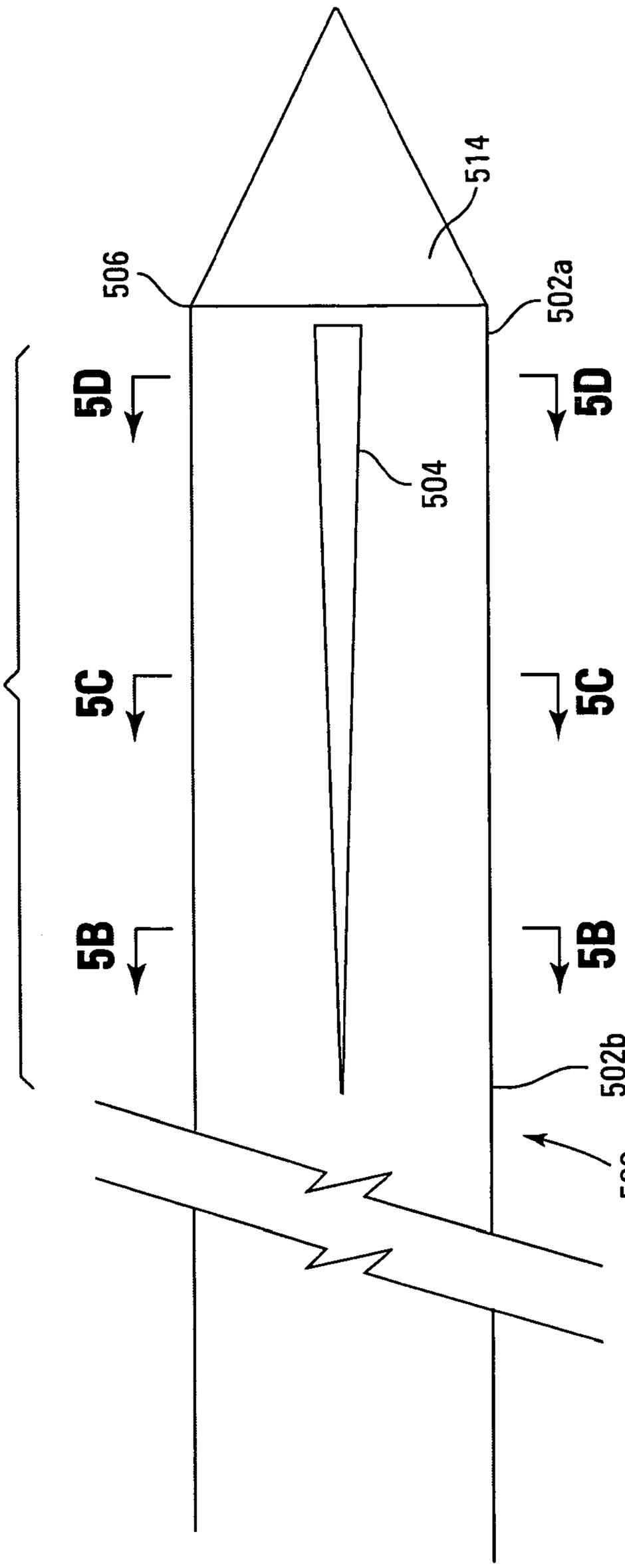


FIG. 5

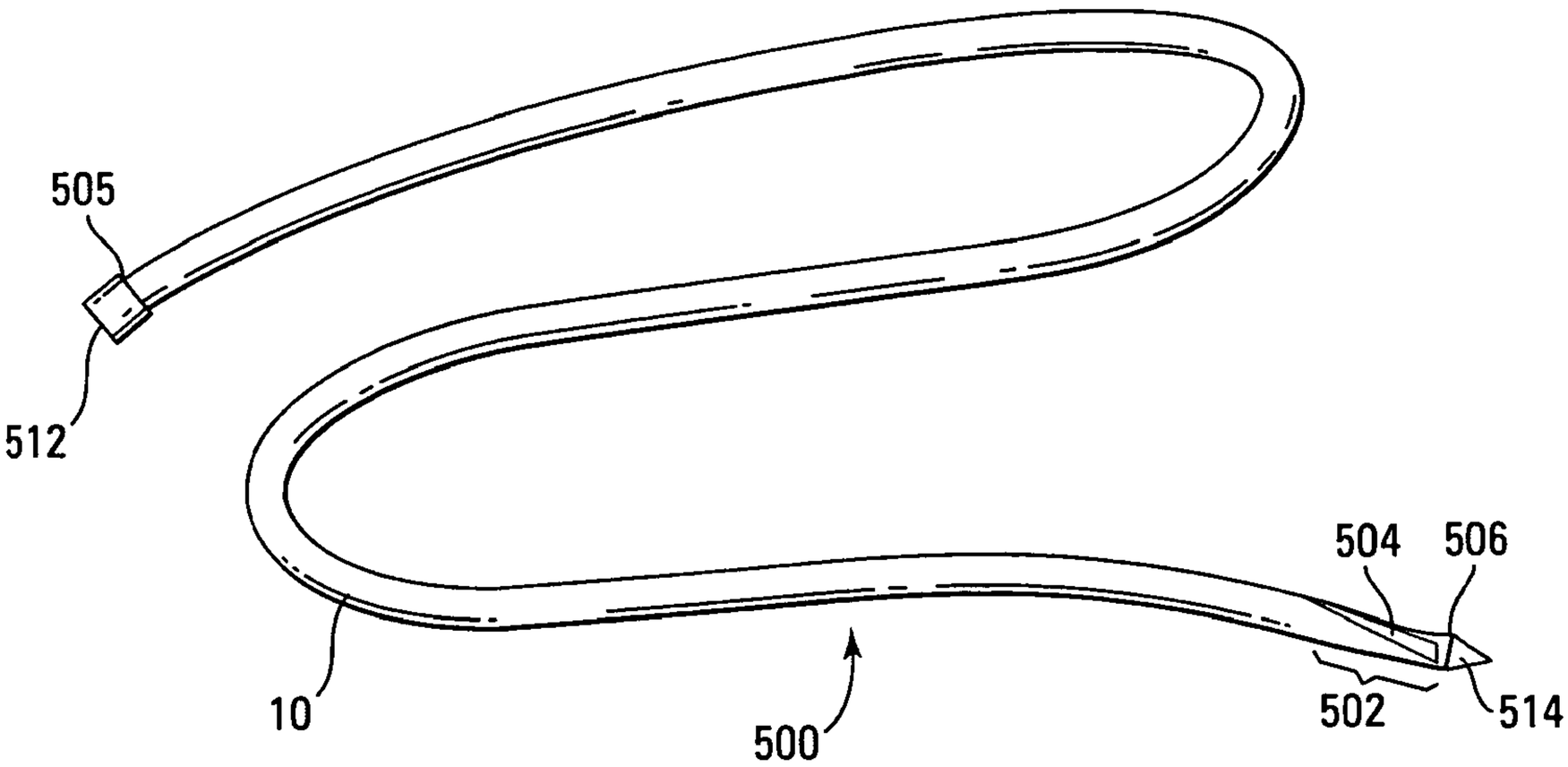


FIG. 5A

FIG. 5B

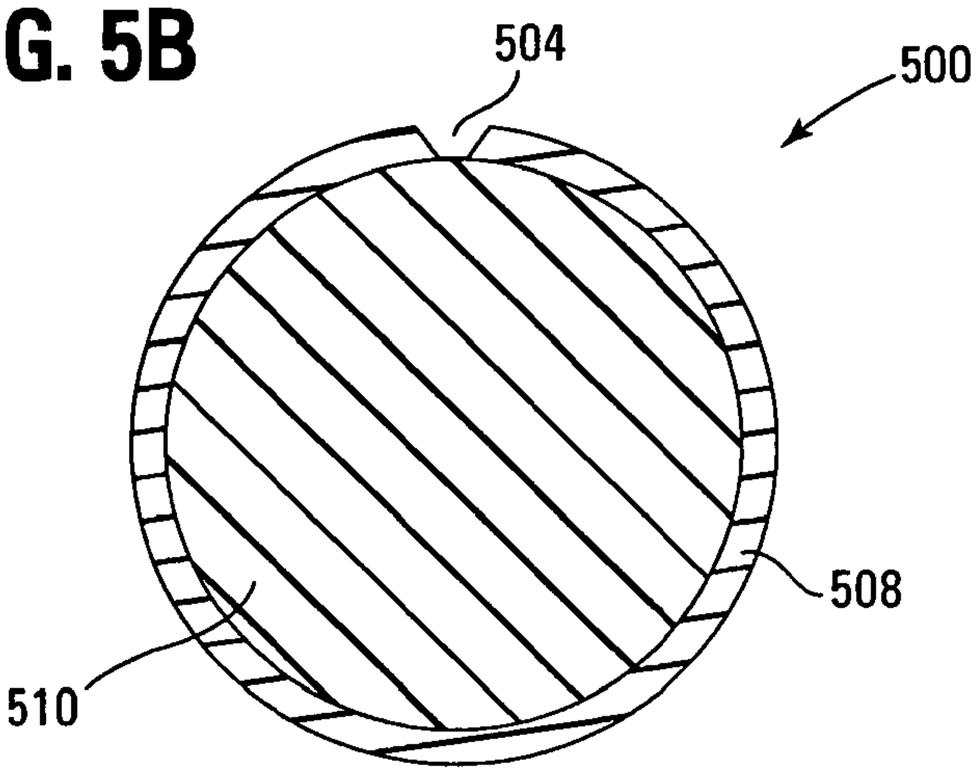


FIG. 5C

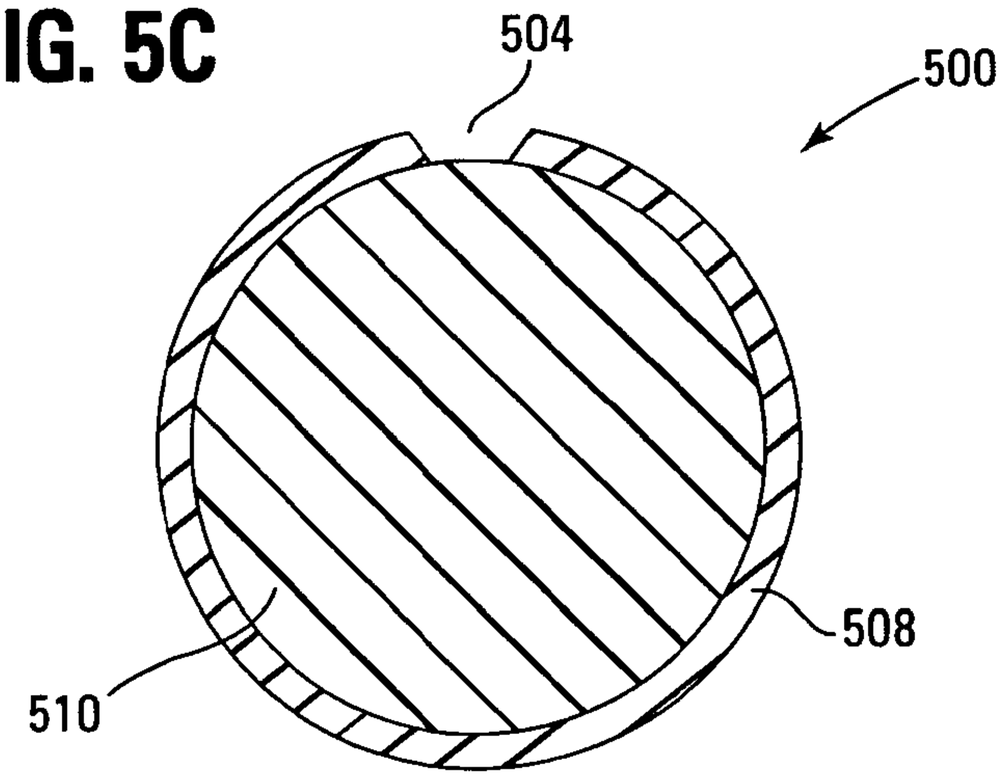
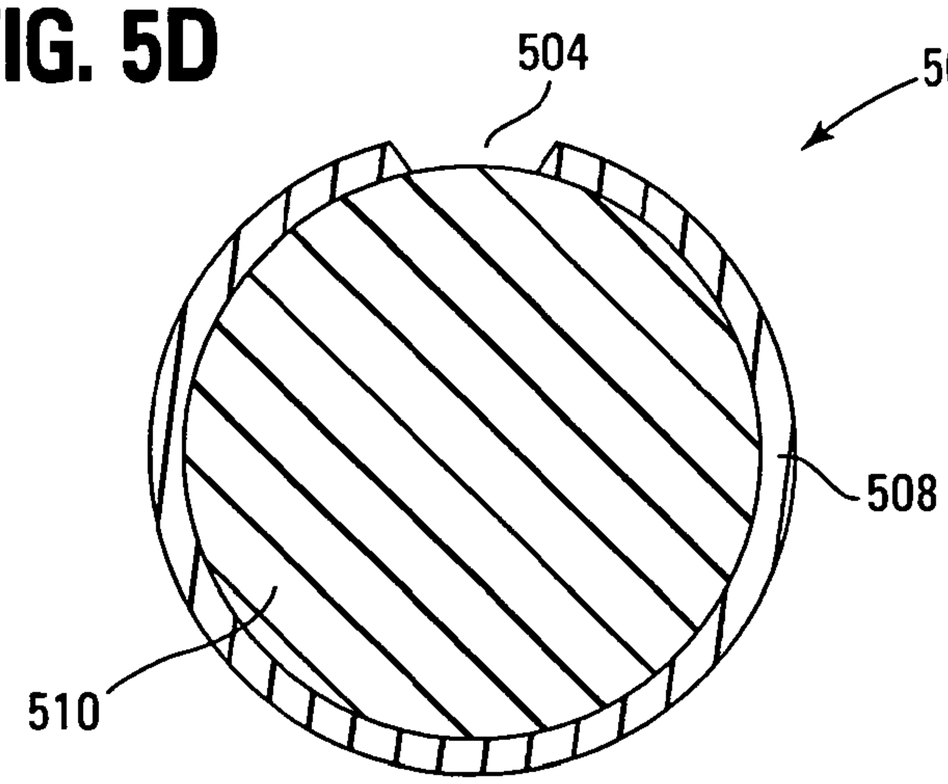


FIG. 5D



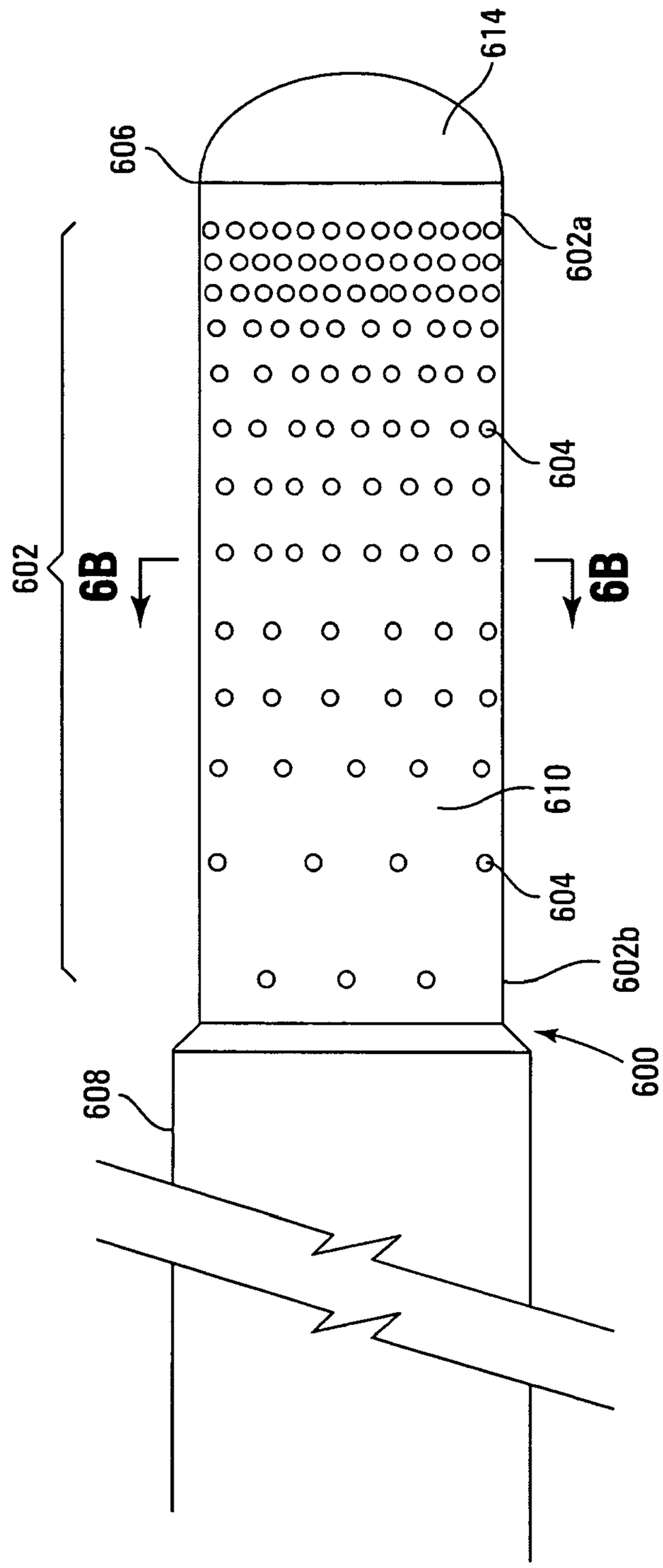


FIG. 6

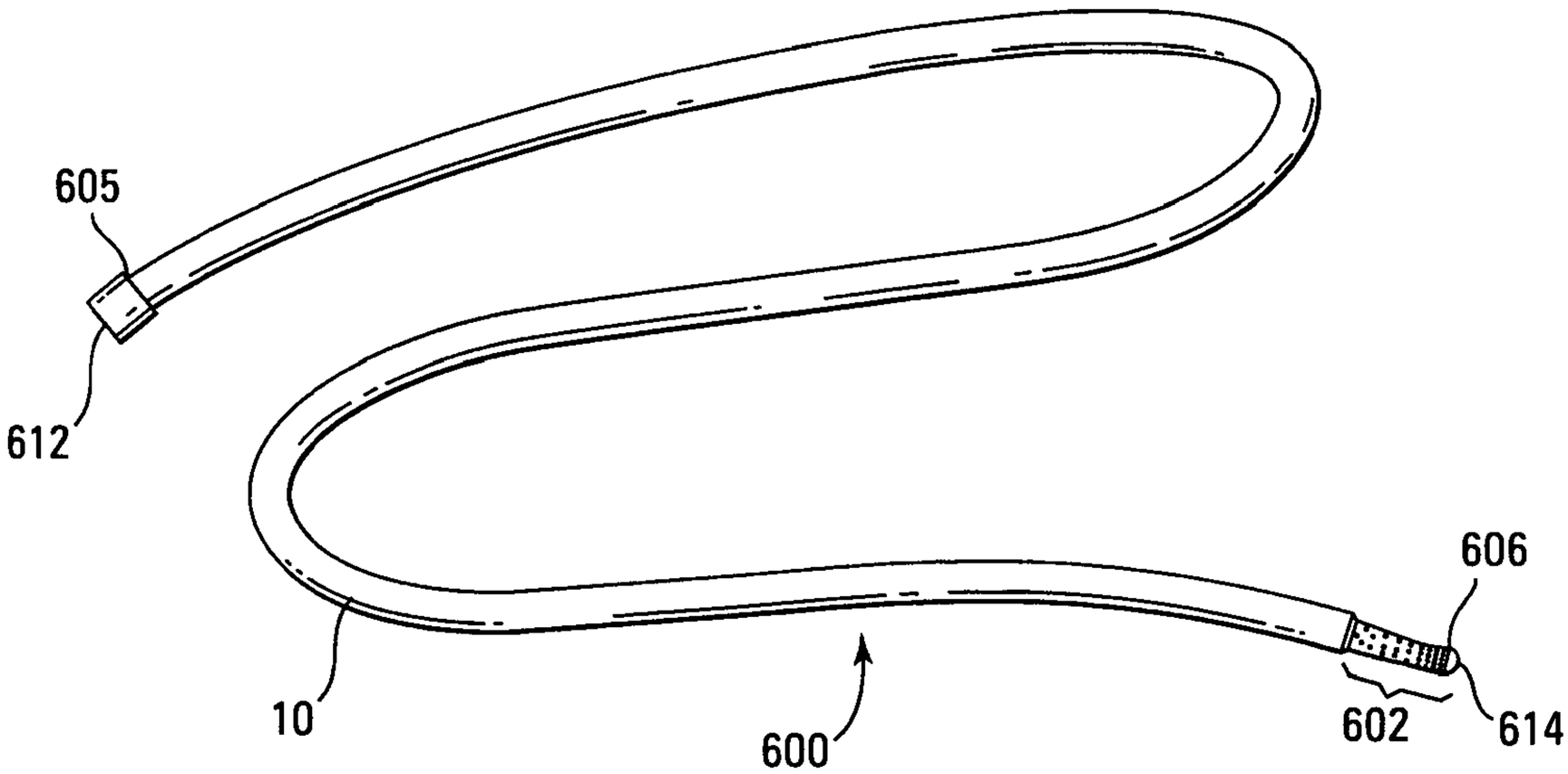


FIG. 6A

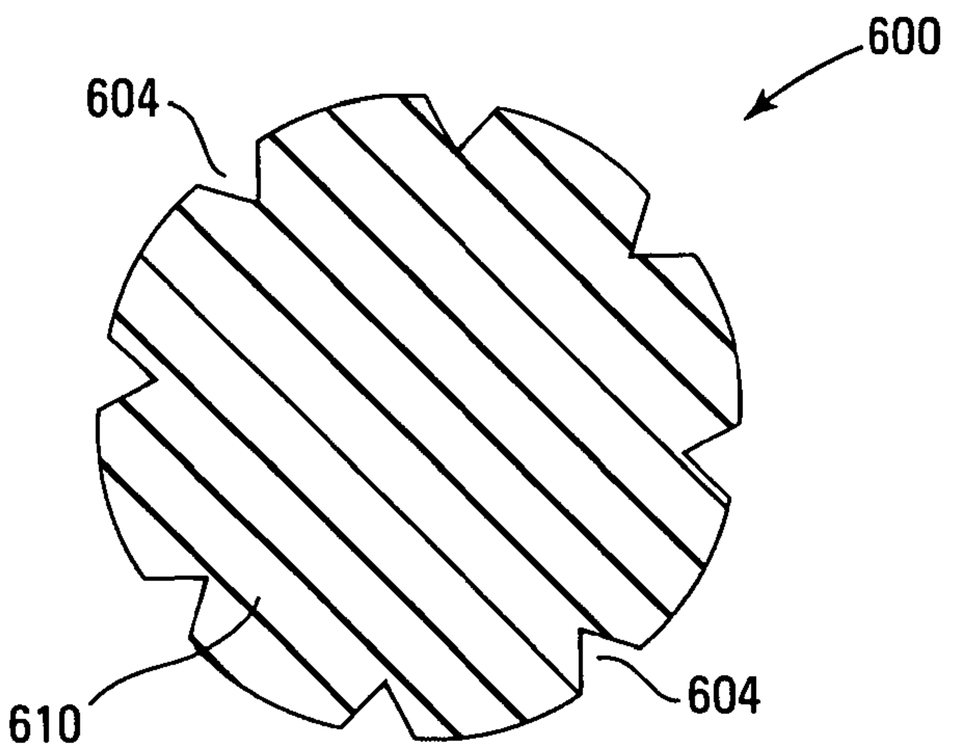


FIG. 6B

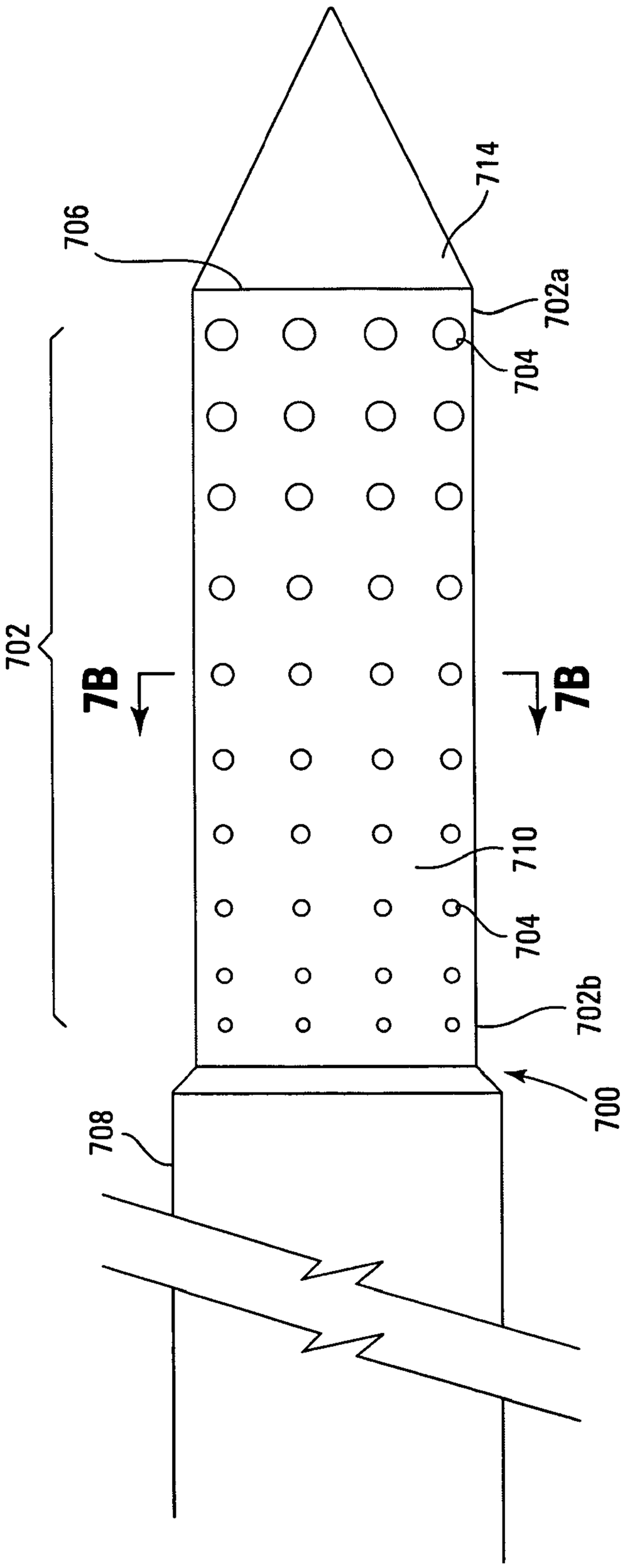


FIG. 7

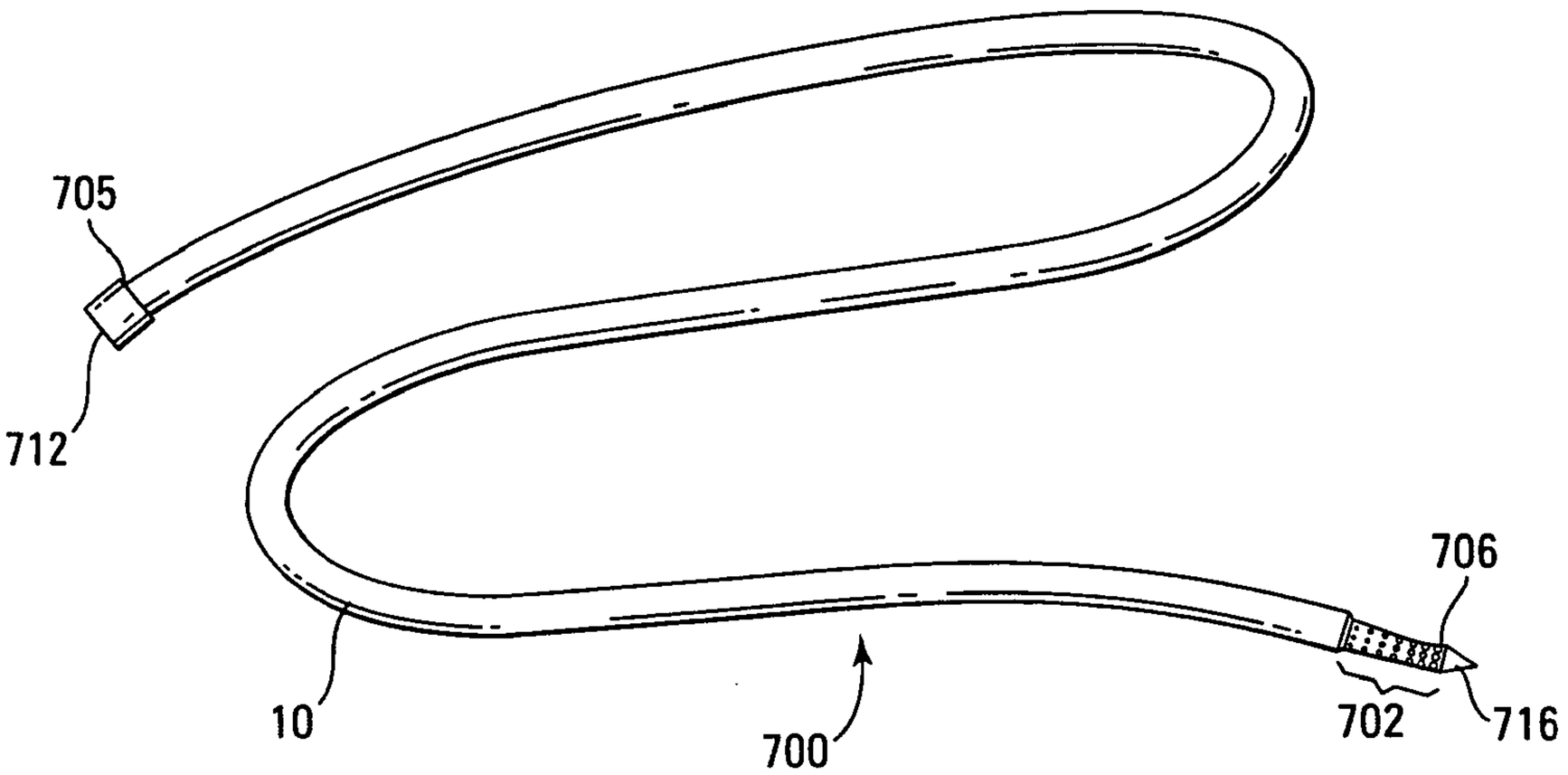


FIG. 7A

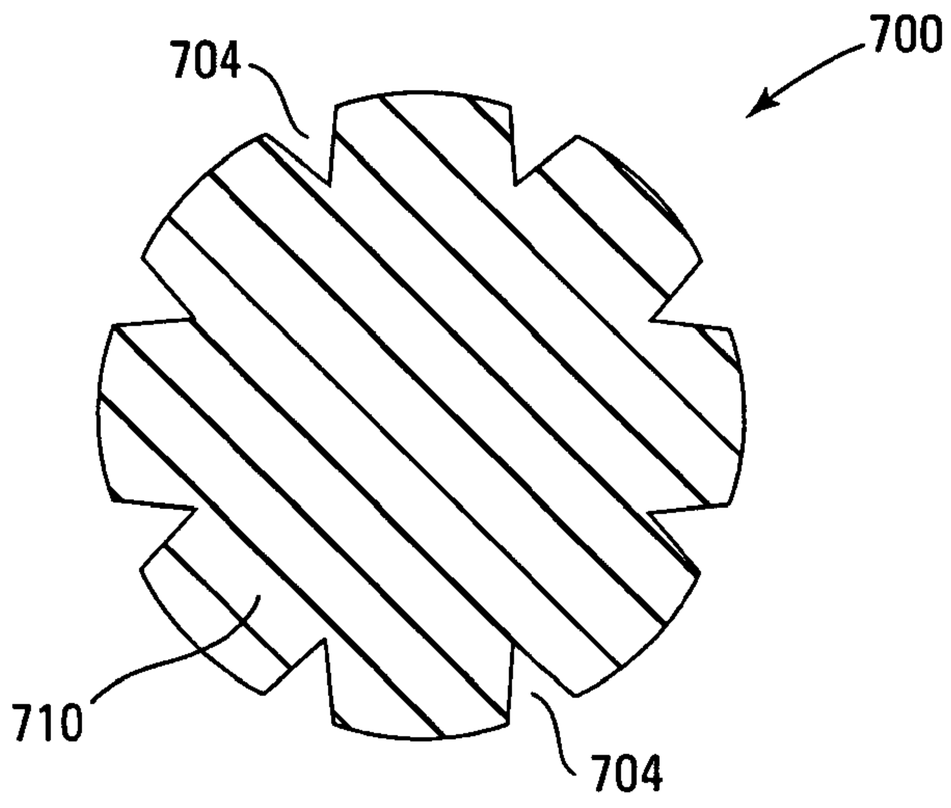


FIG. 7B

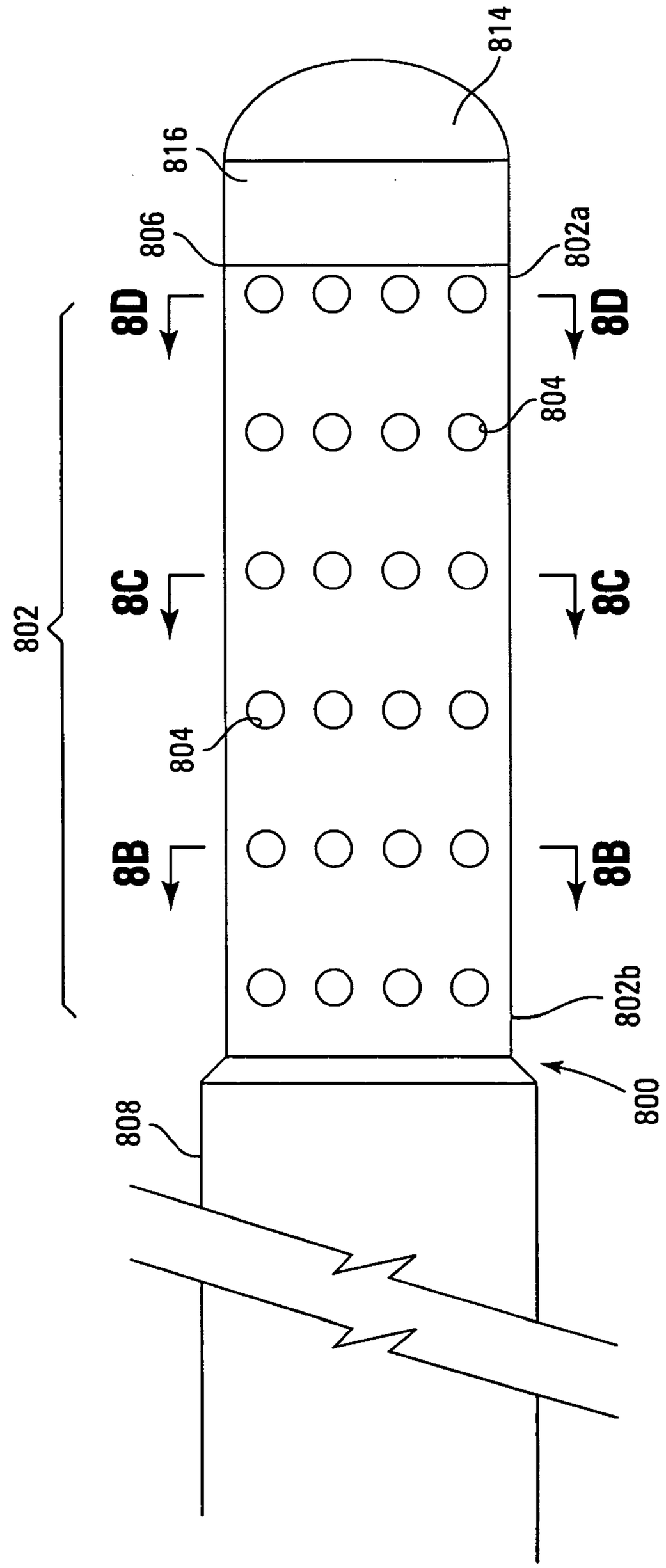


FIG. 8

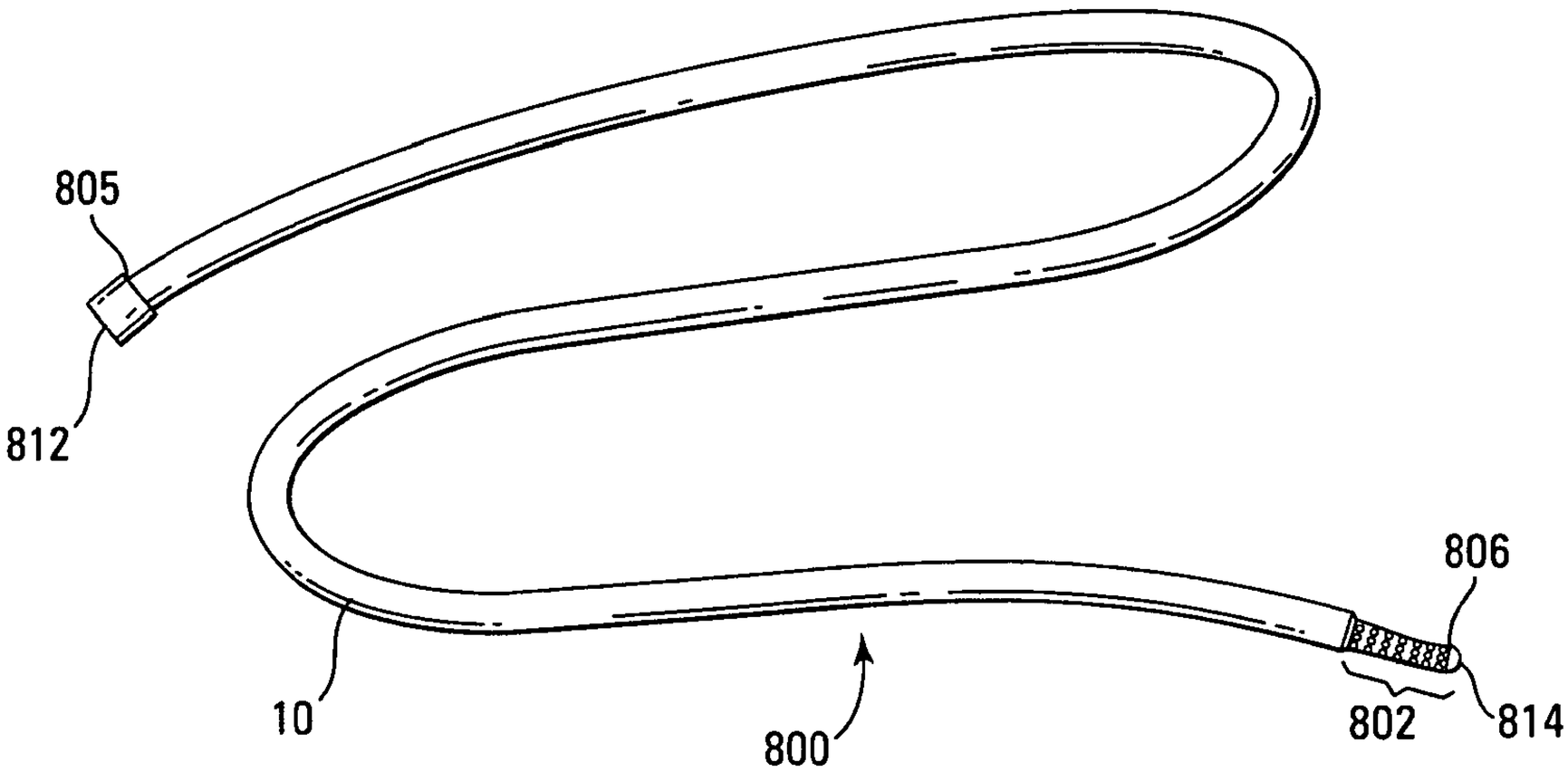


FIG. 8A

FIG. 8B

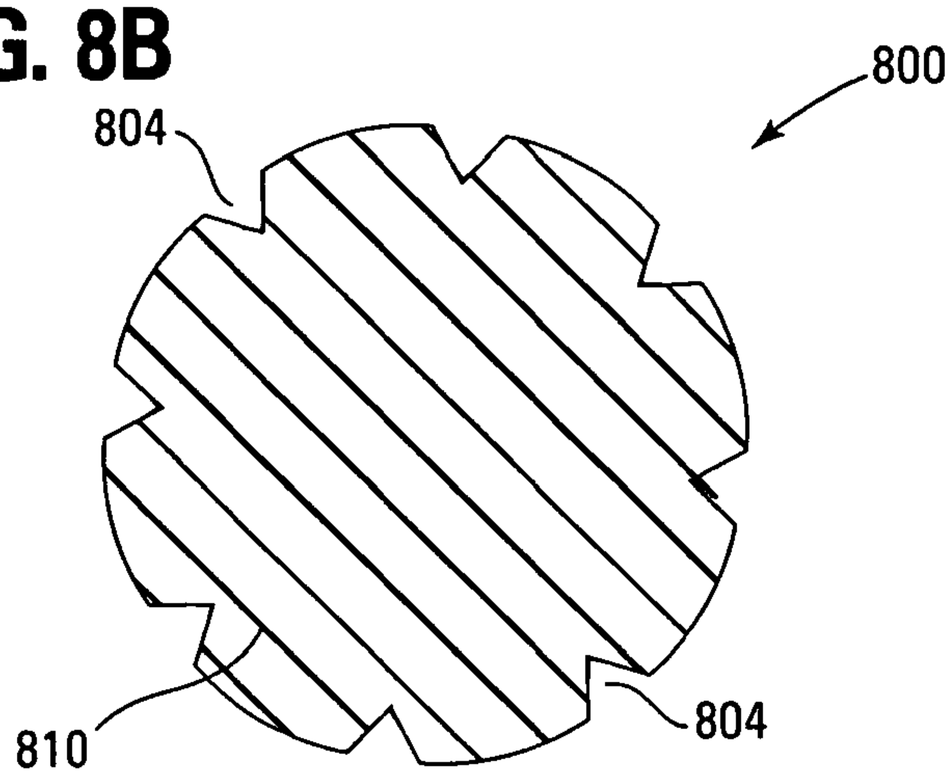


FIG. 8C

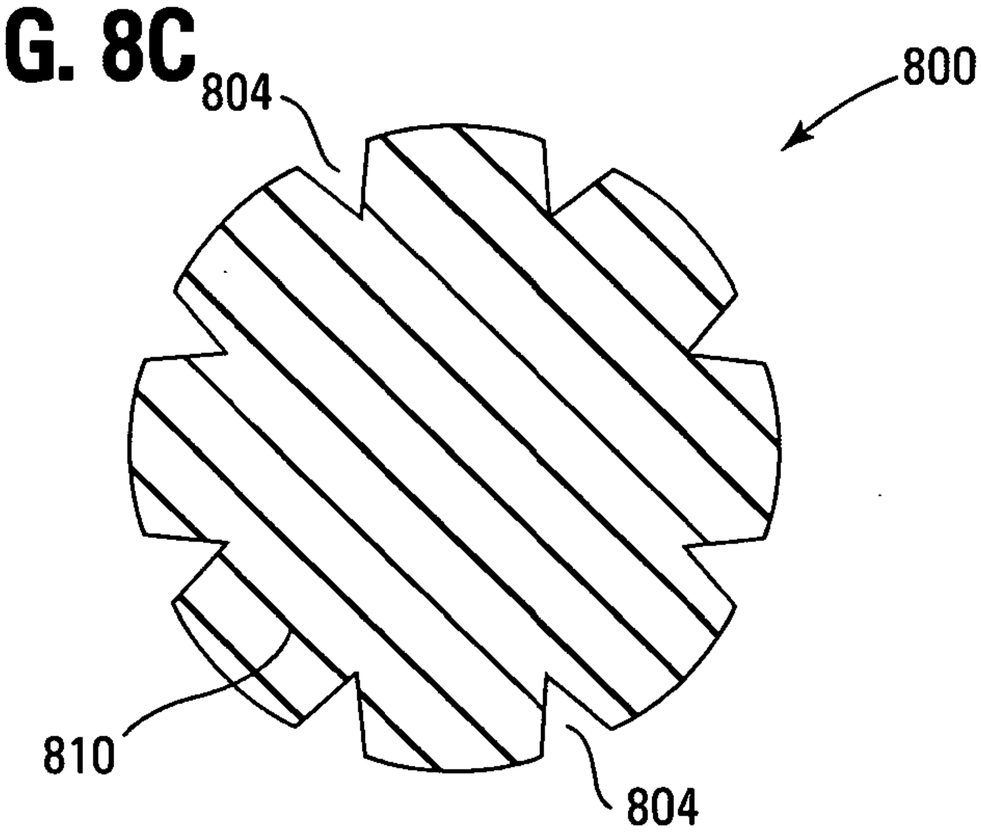
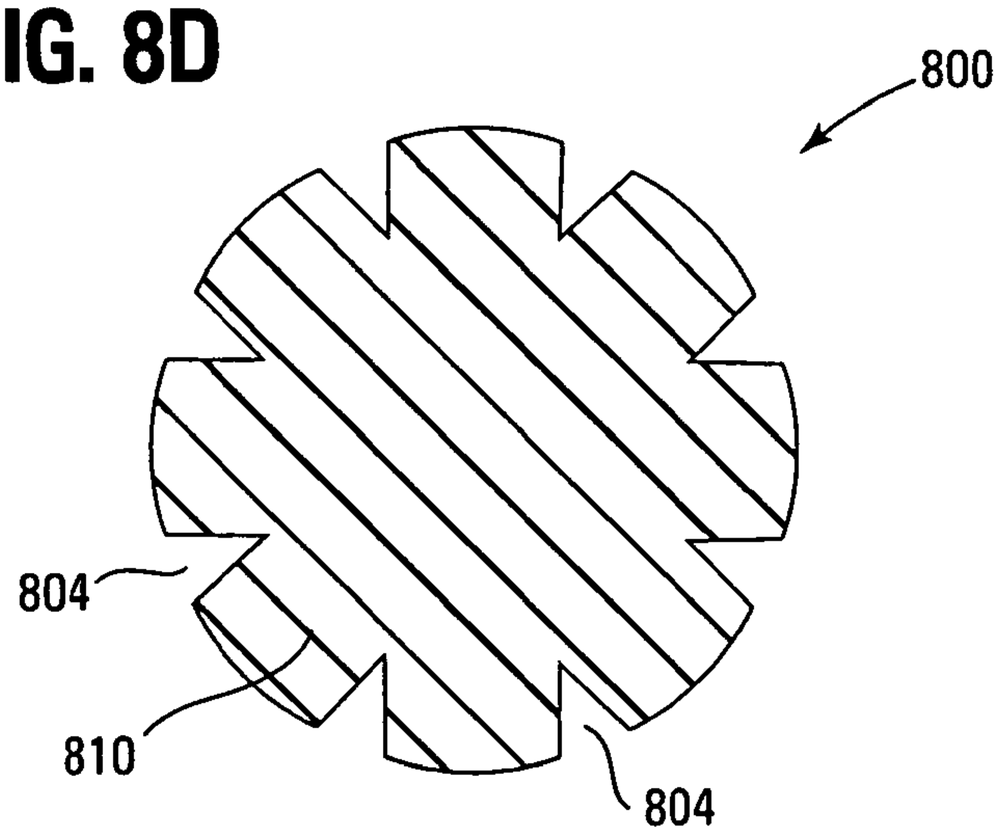


FIG. 8D



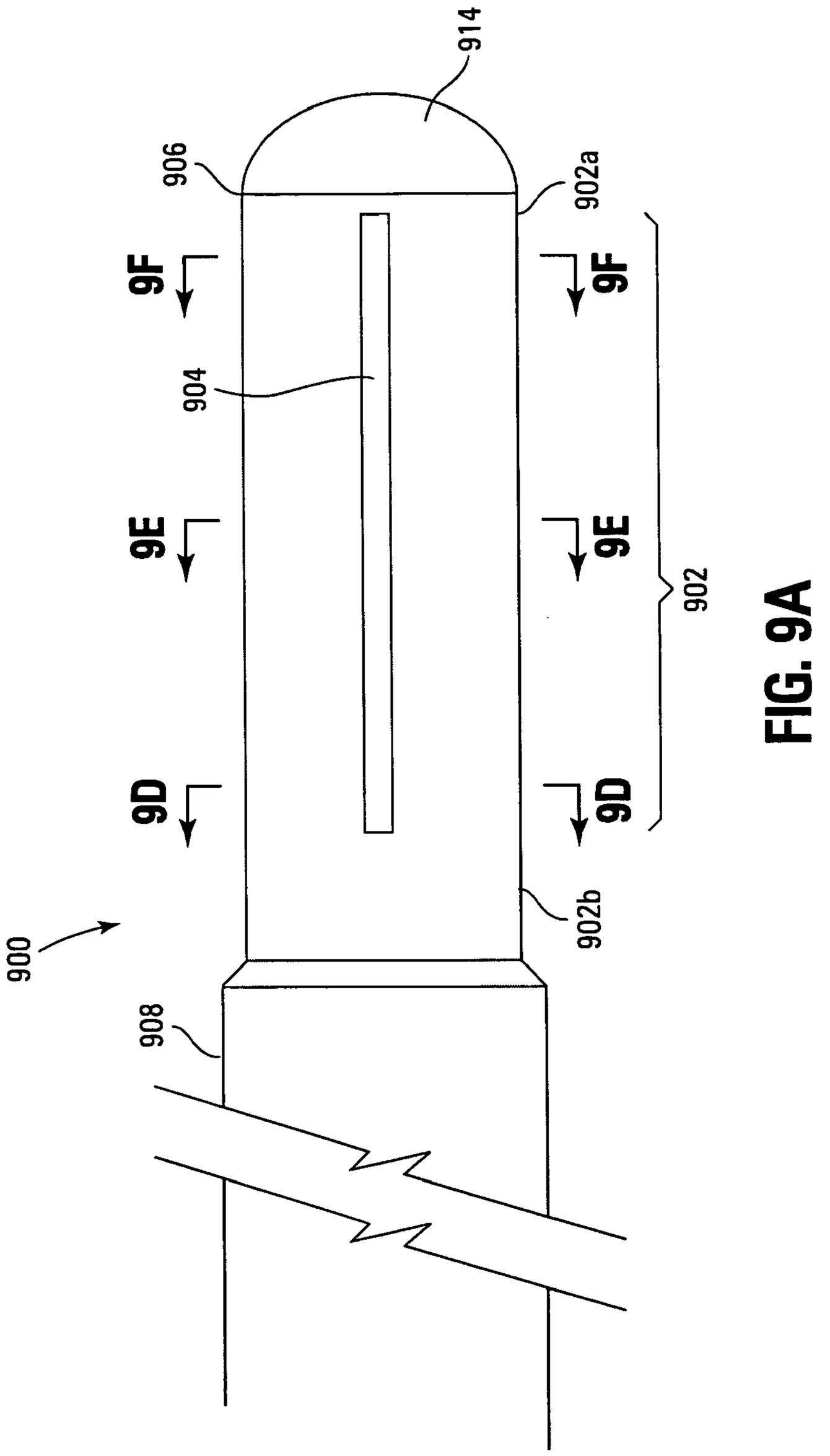


FIG. 9A

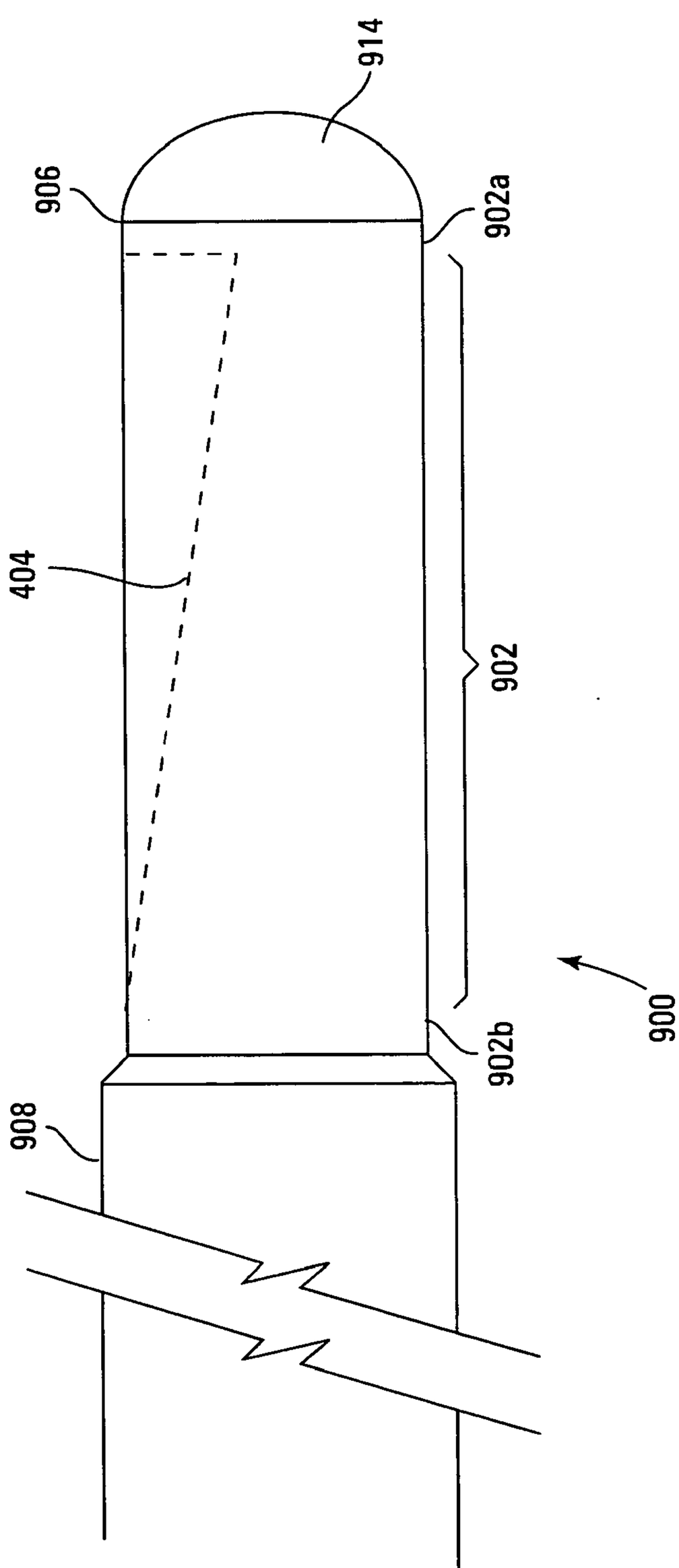


FIG. 9B

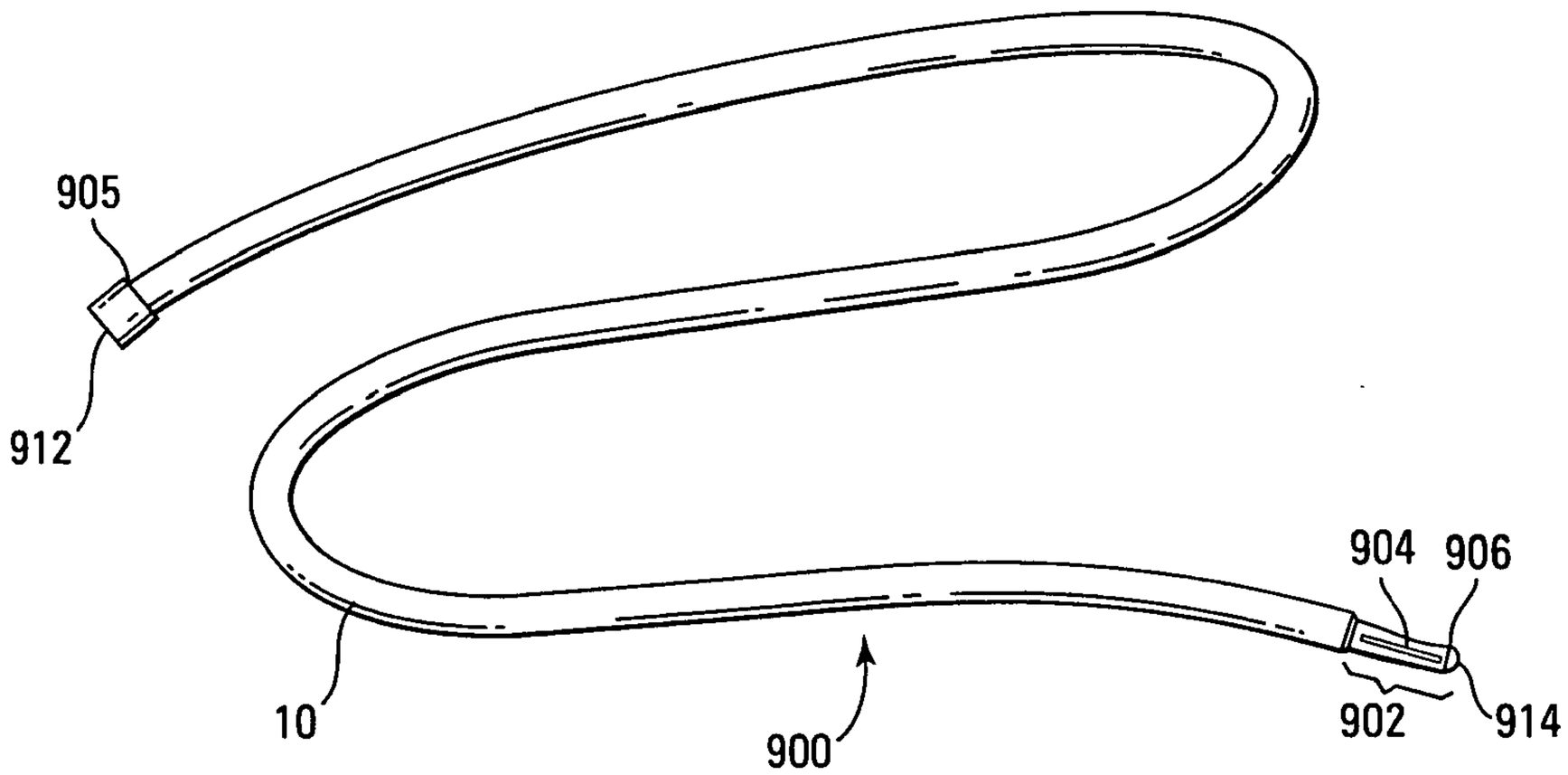


FIG. 9C

FIG. 9D

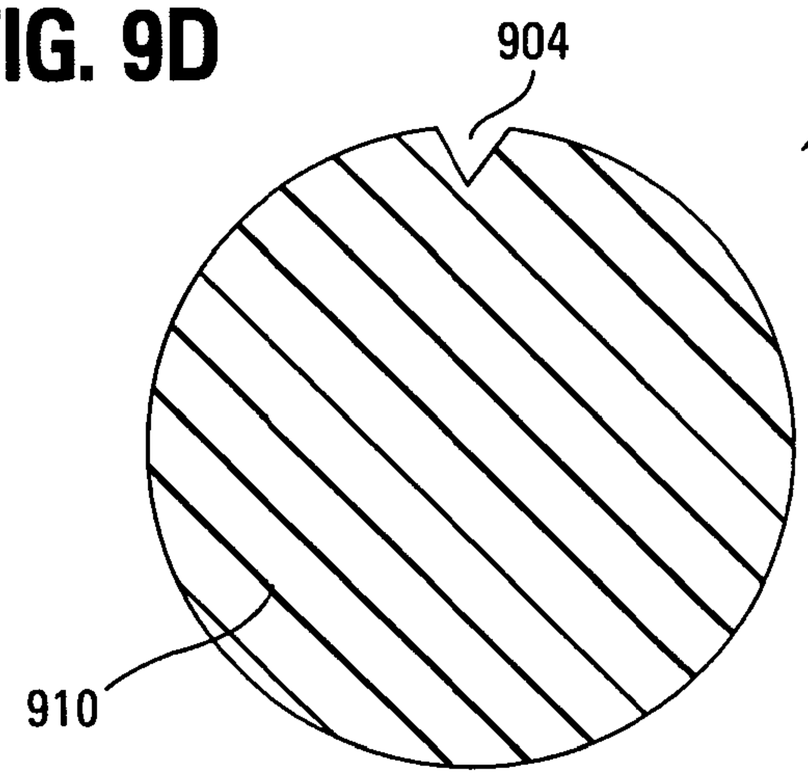


FIG. 9E

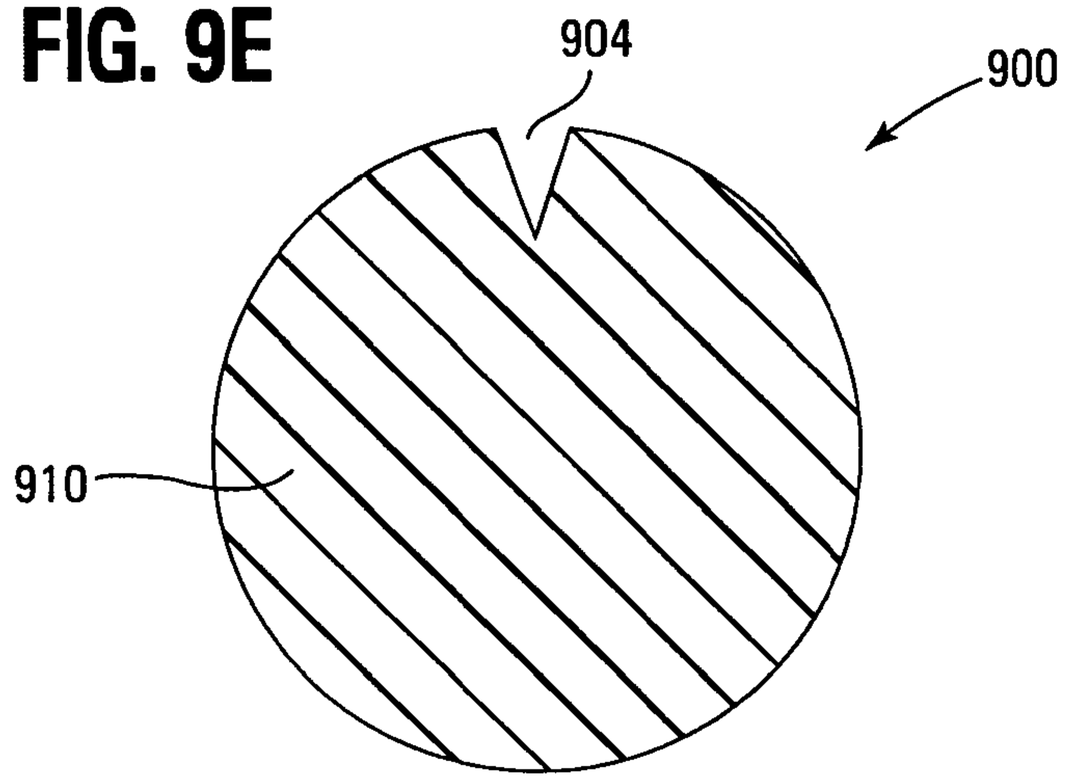
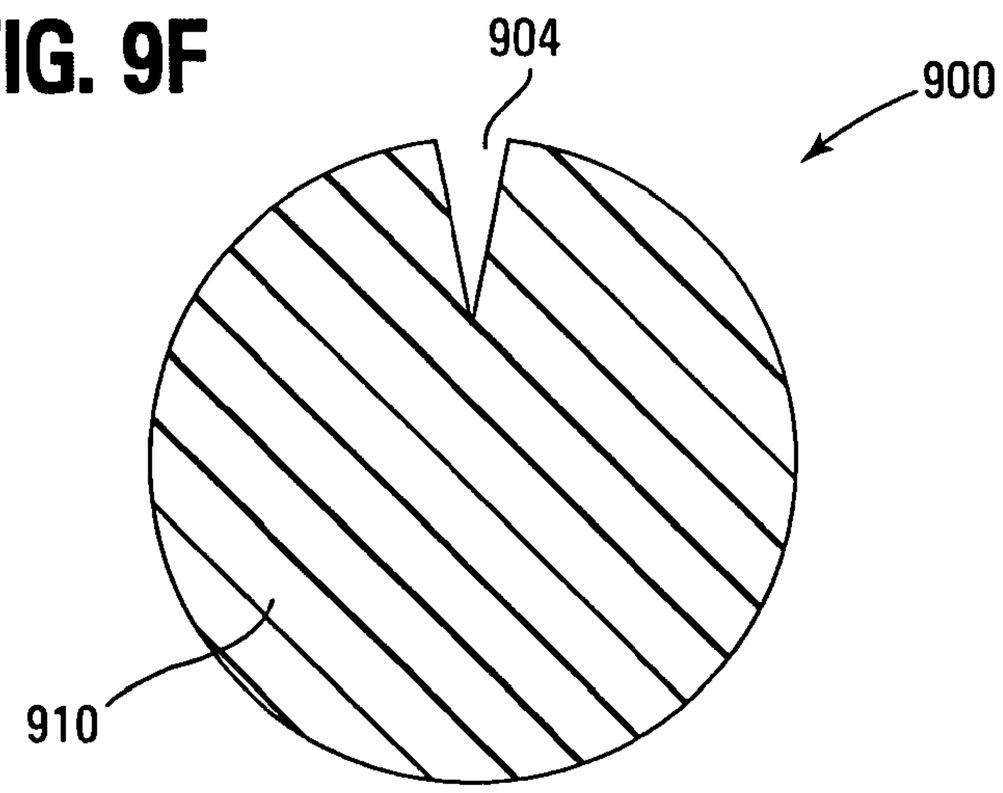
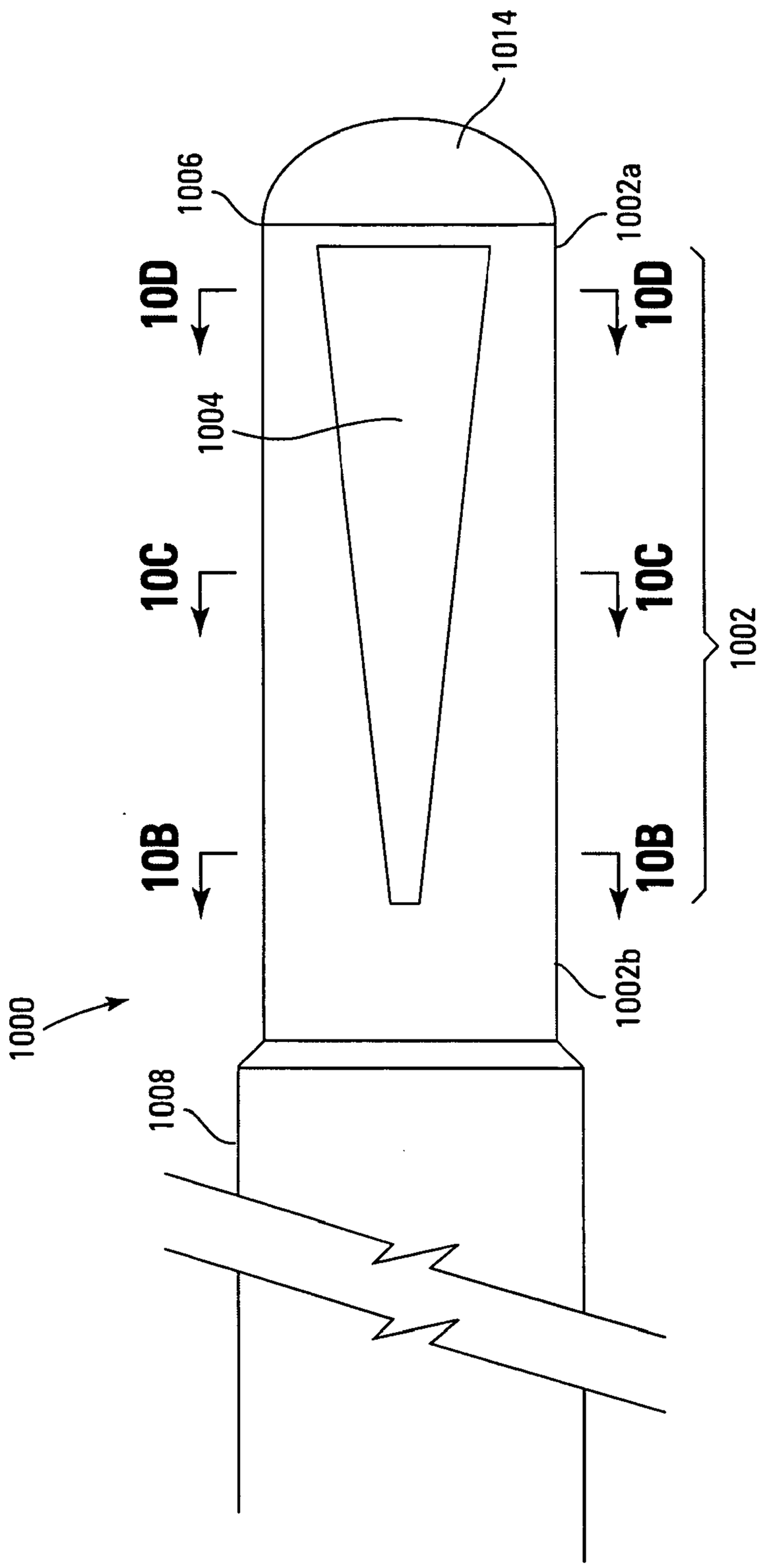


FIG. 9F

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1002b
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1008

FIG. 10

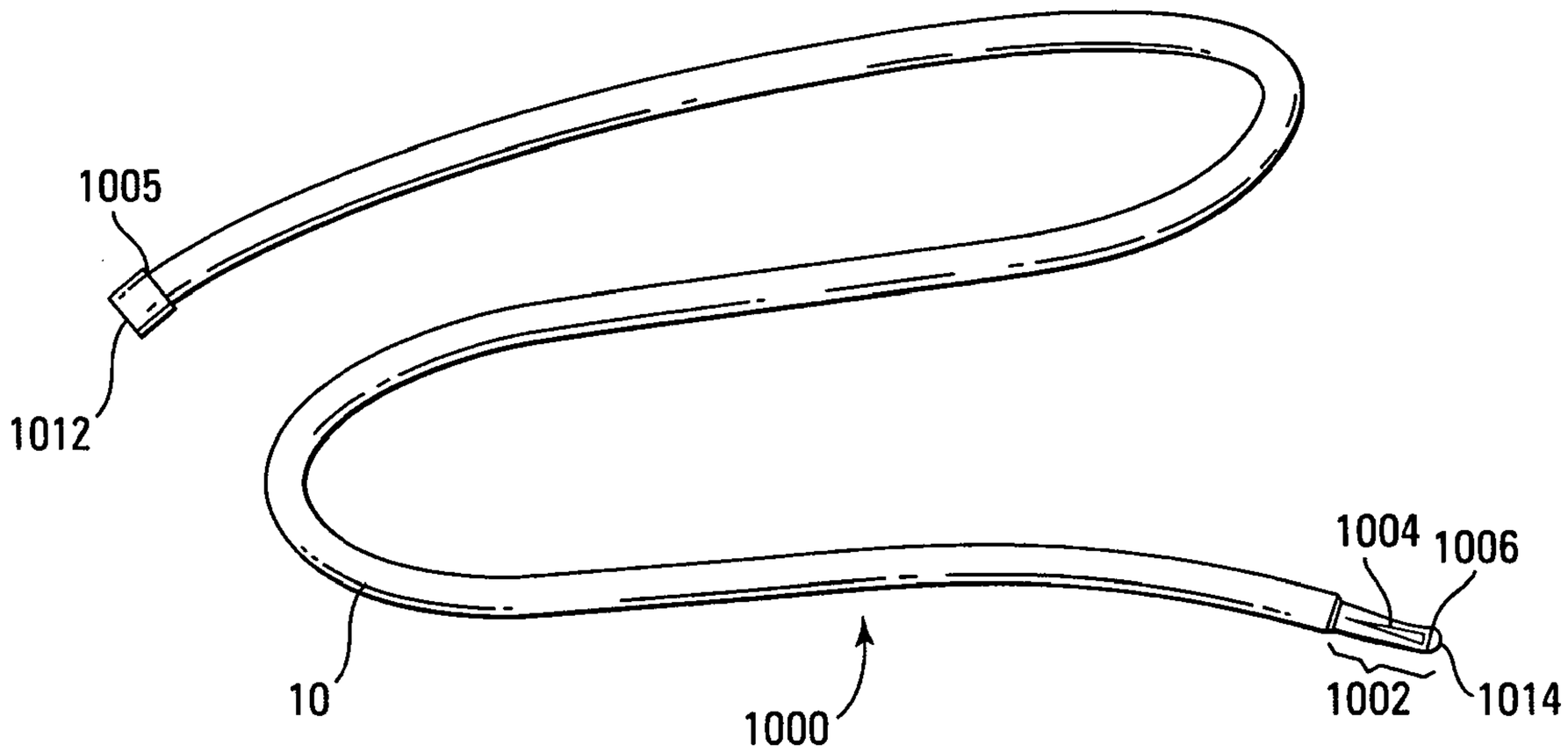


FIG. 10A

FIG. 10B

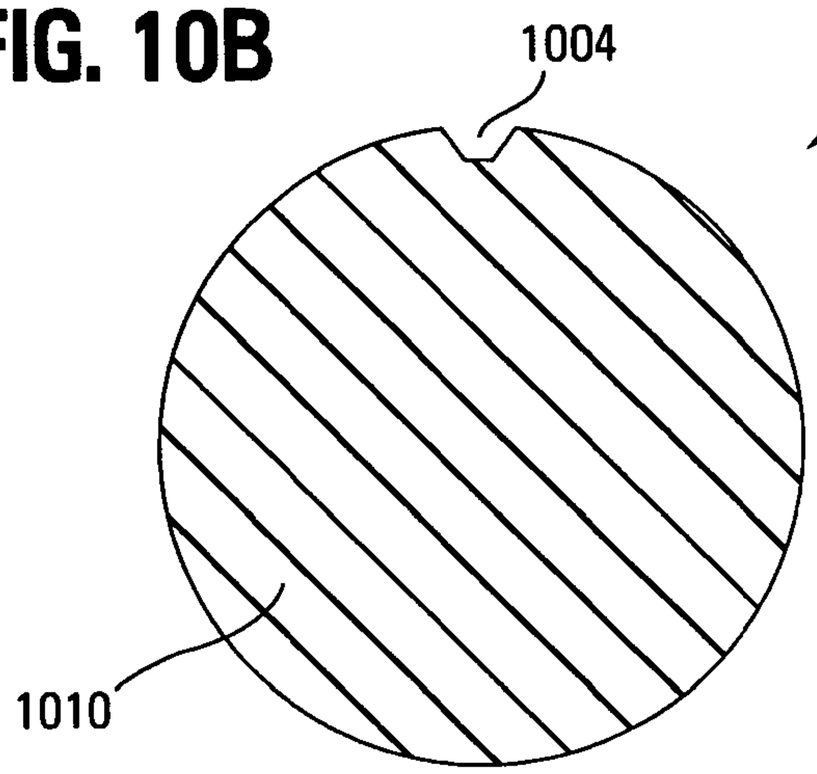


FIG. 10C

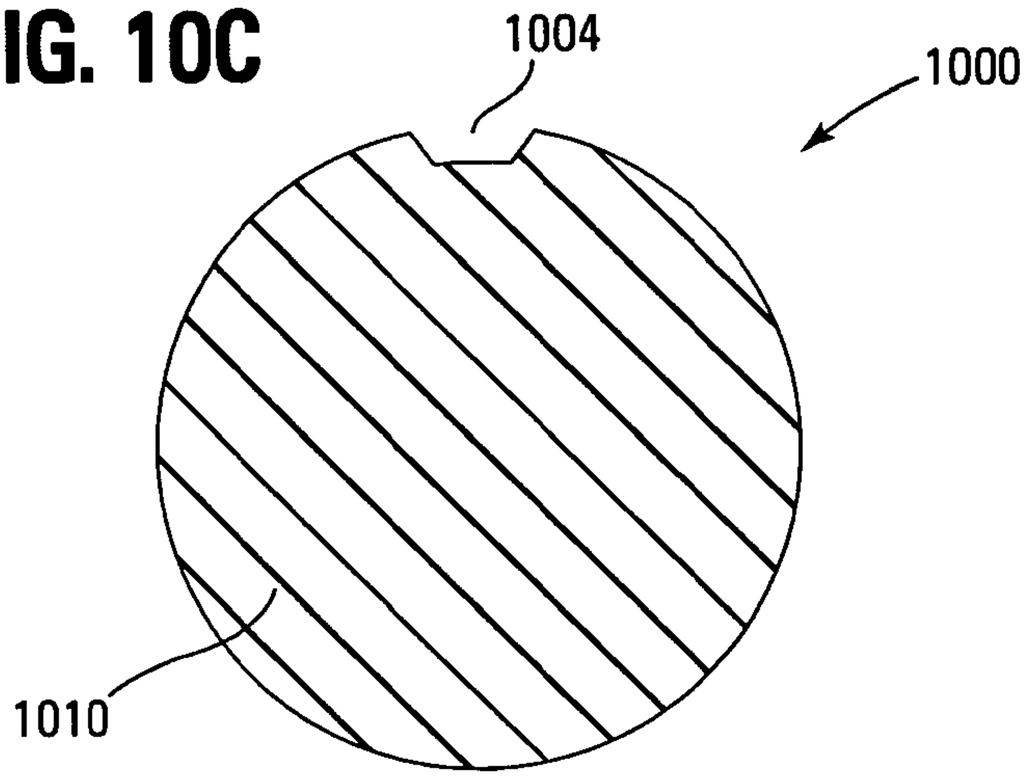
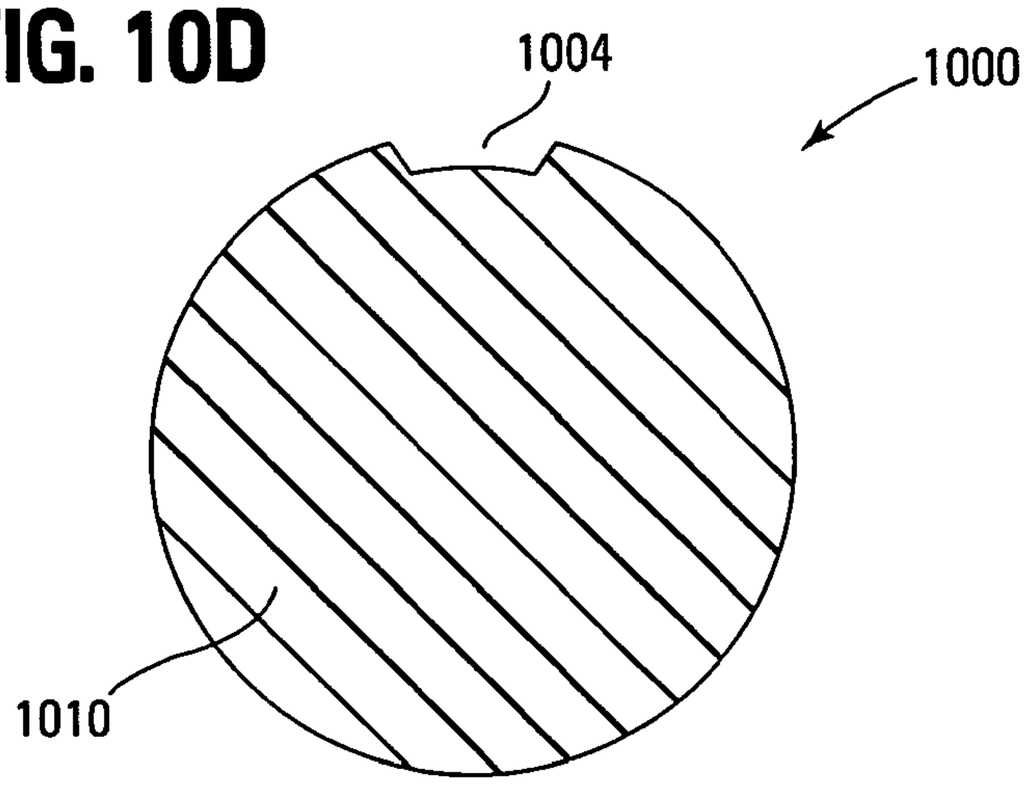


FIG. 10D



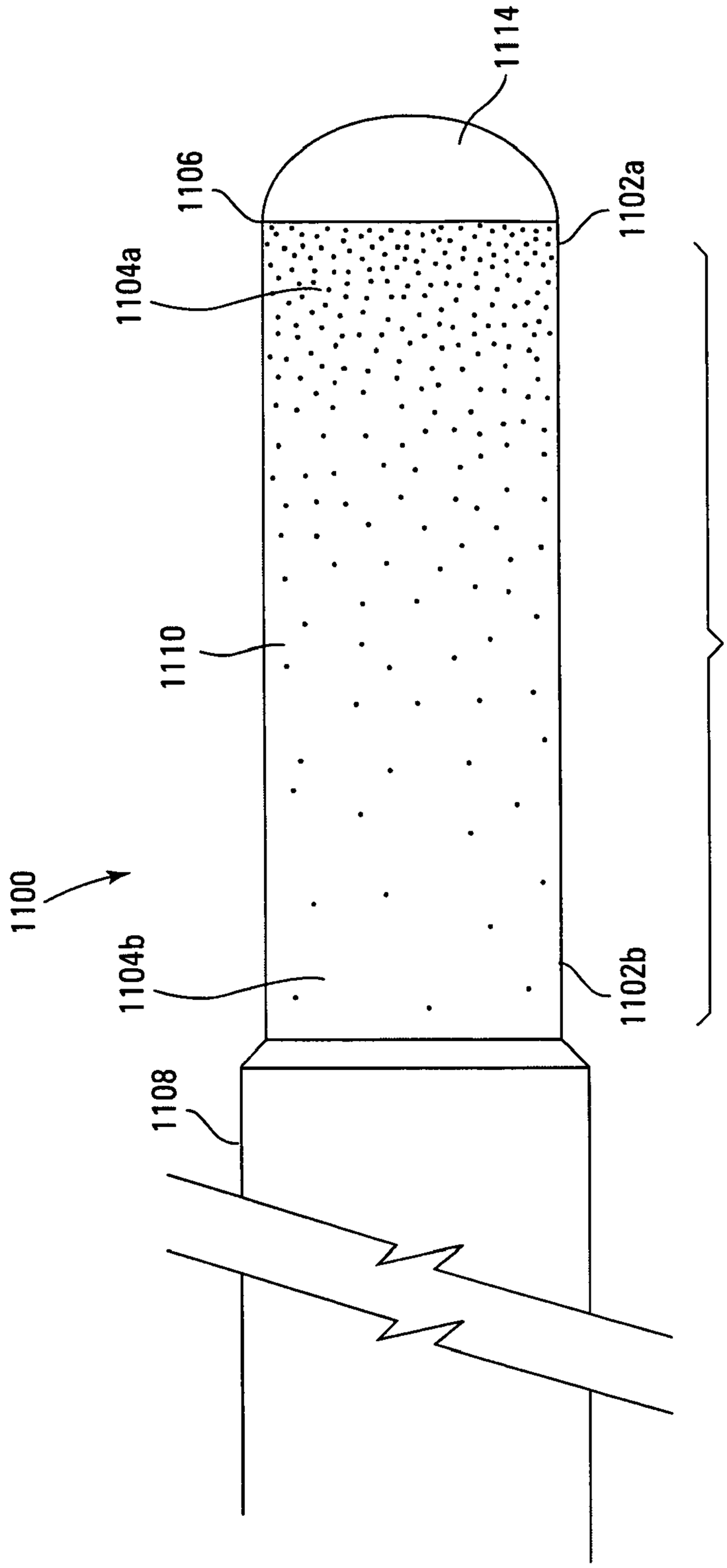


FIG. 11

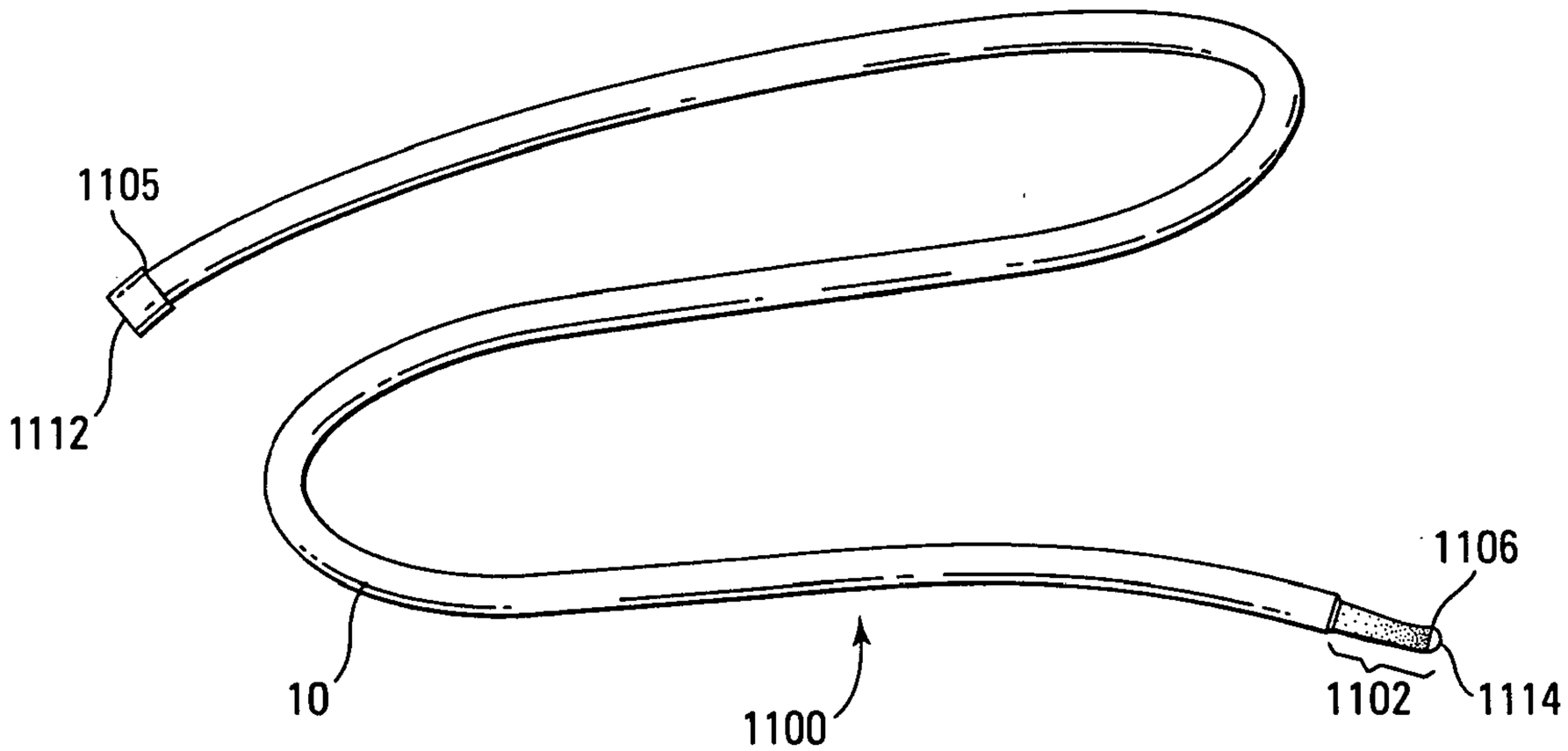


FIG. 11A

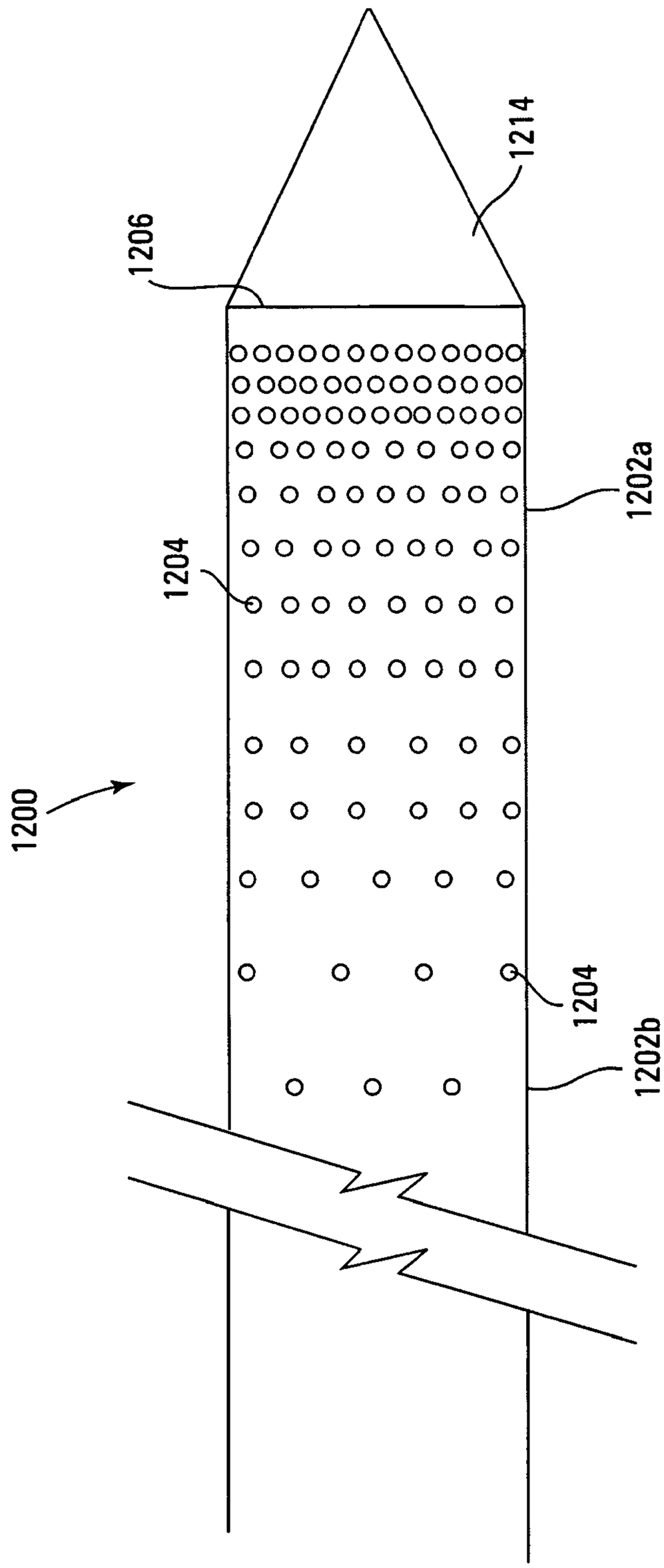


FIG. 12

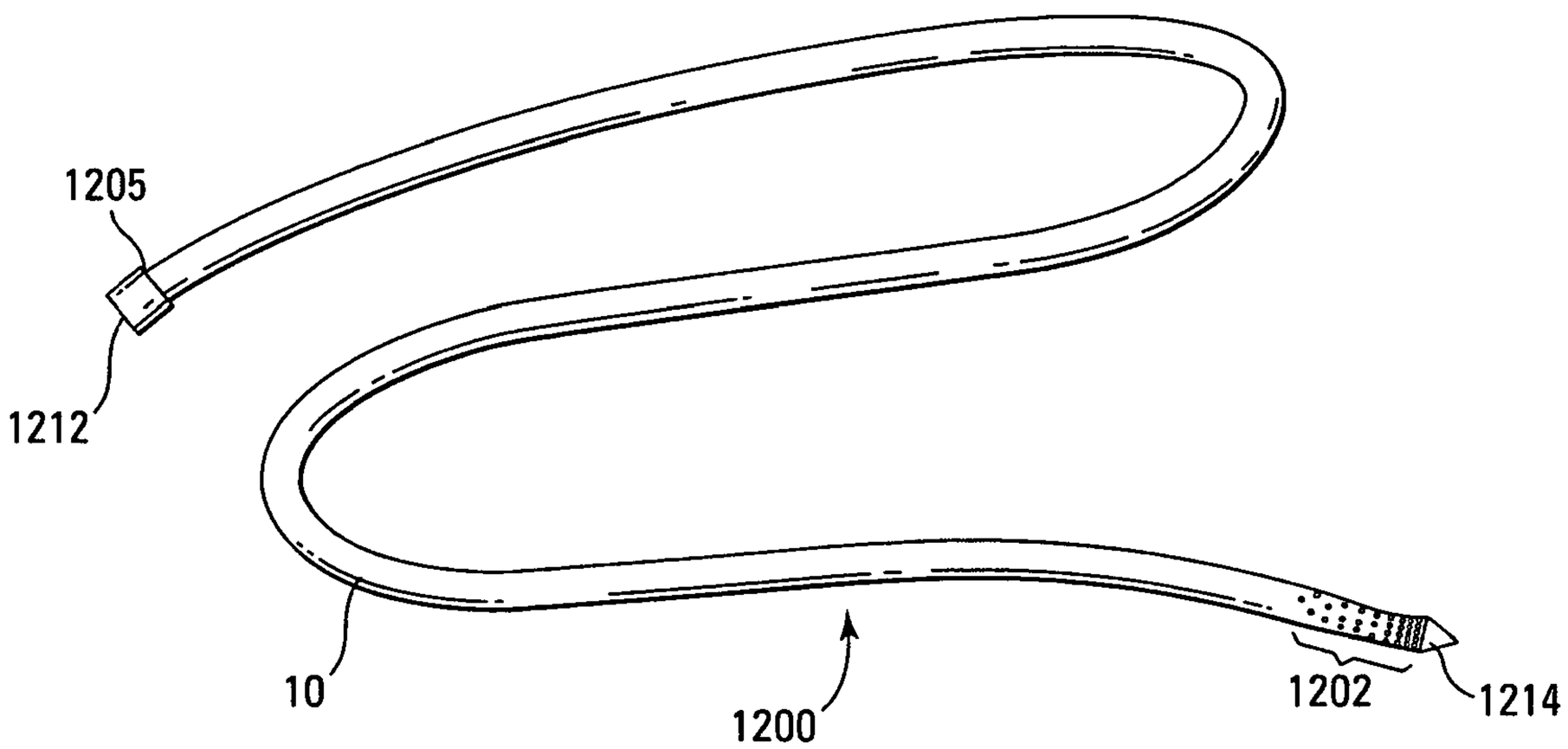
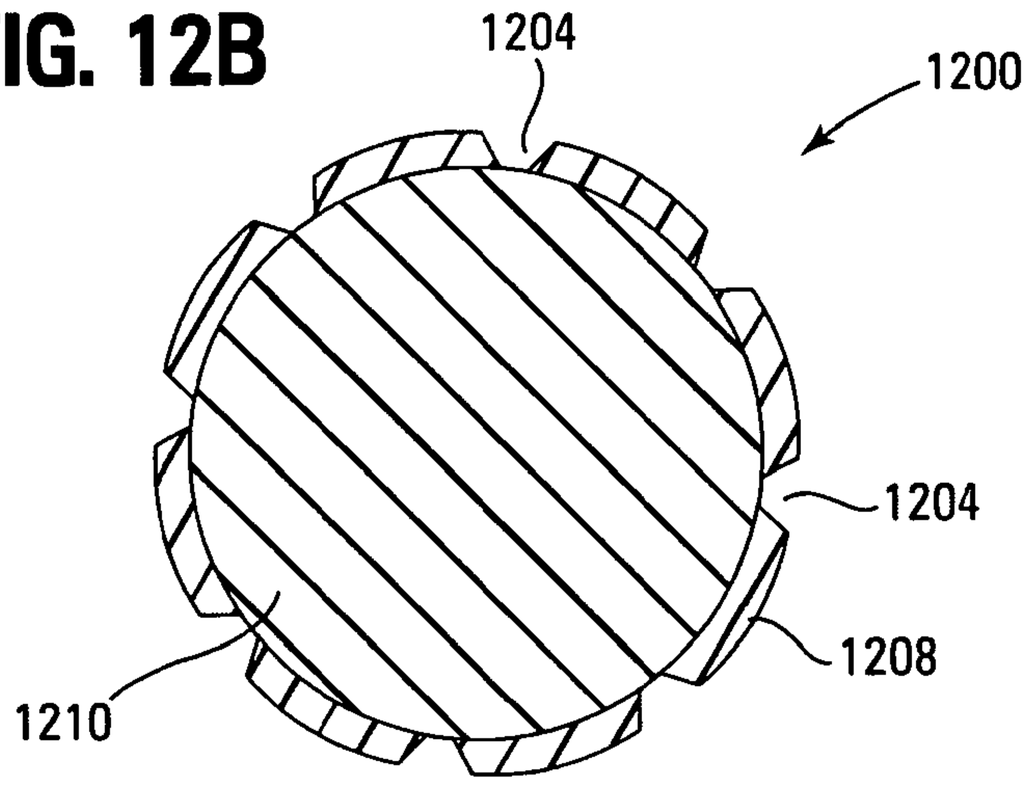


FIG. 12A

FIG. 12B



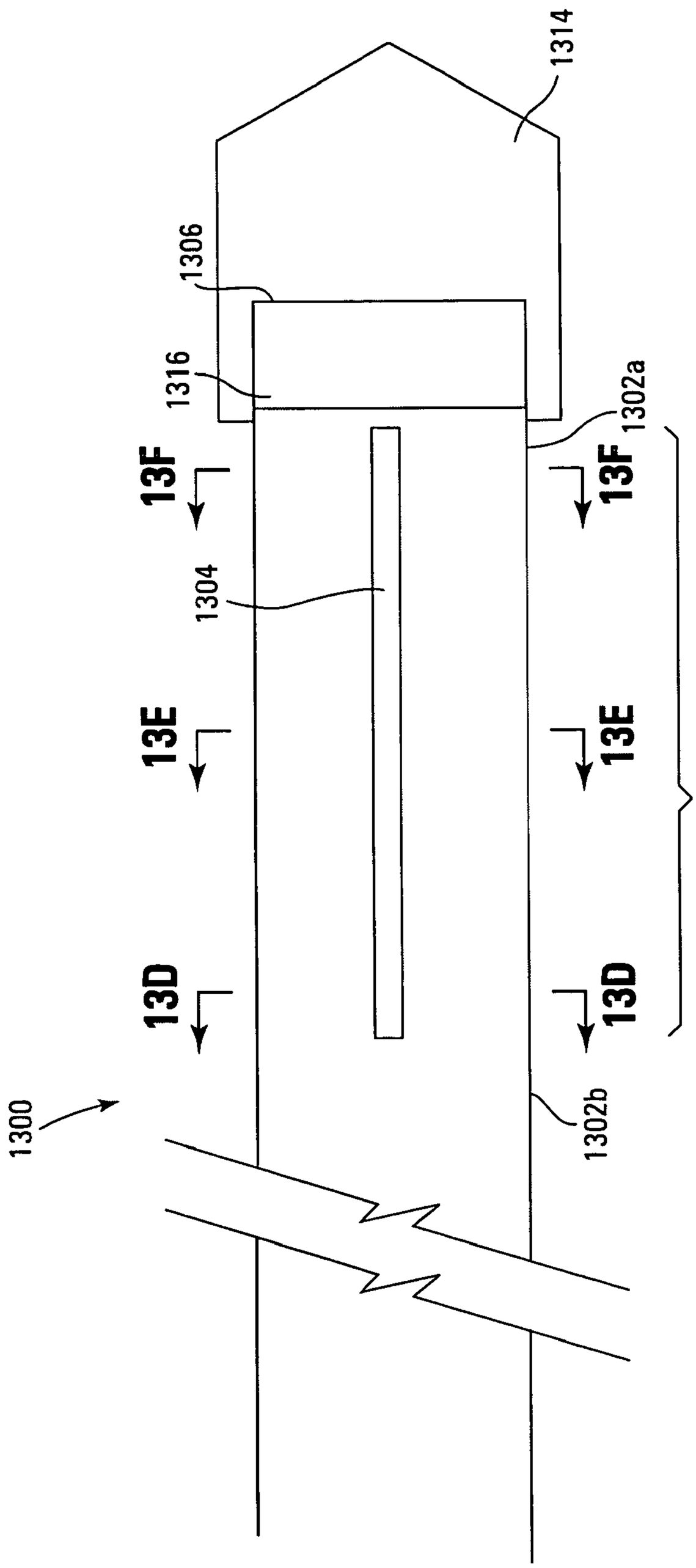

1314
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FIG. 13A

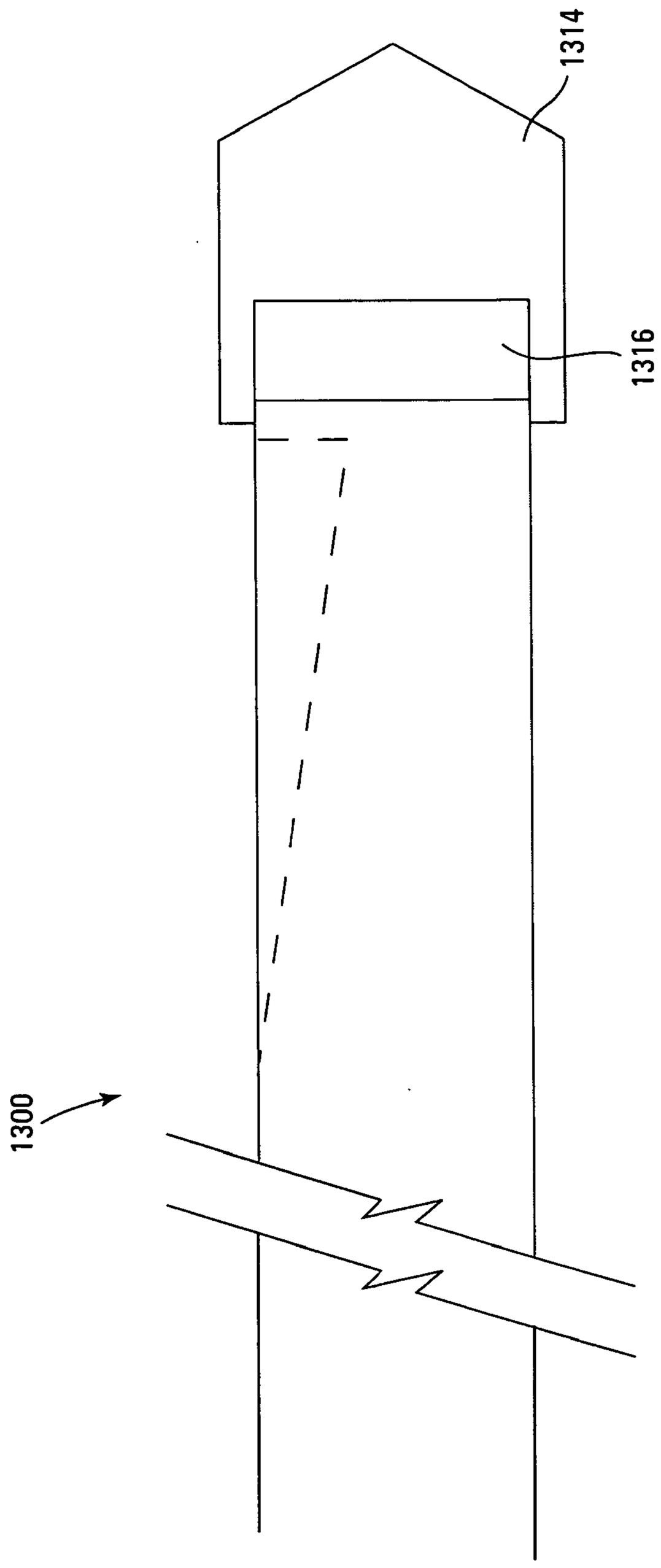


FIG. 13B

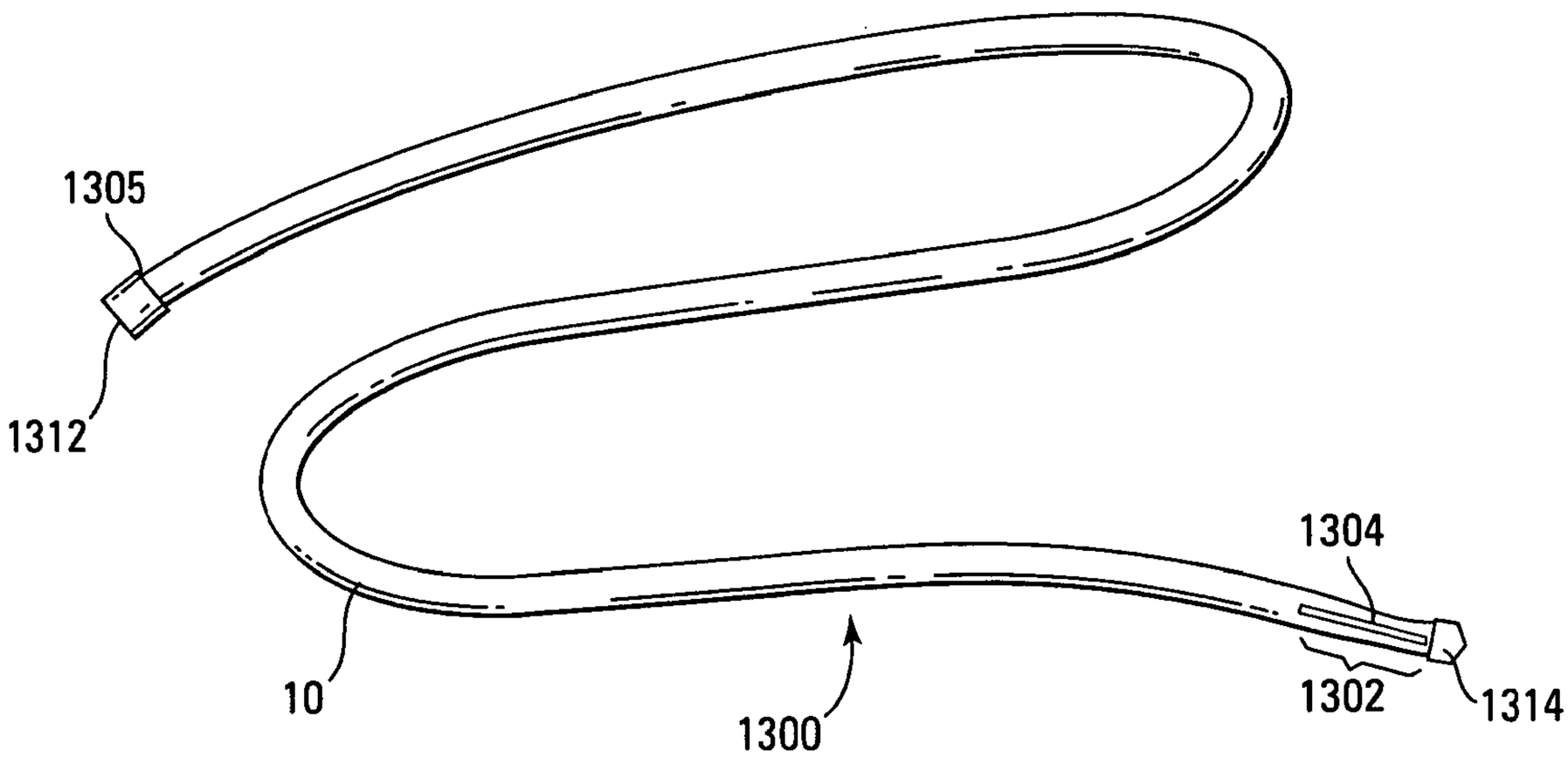


FIG. 13C

FIG. 13D

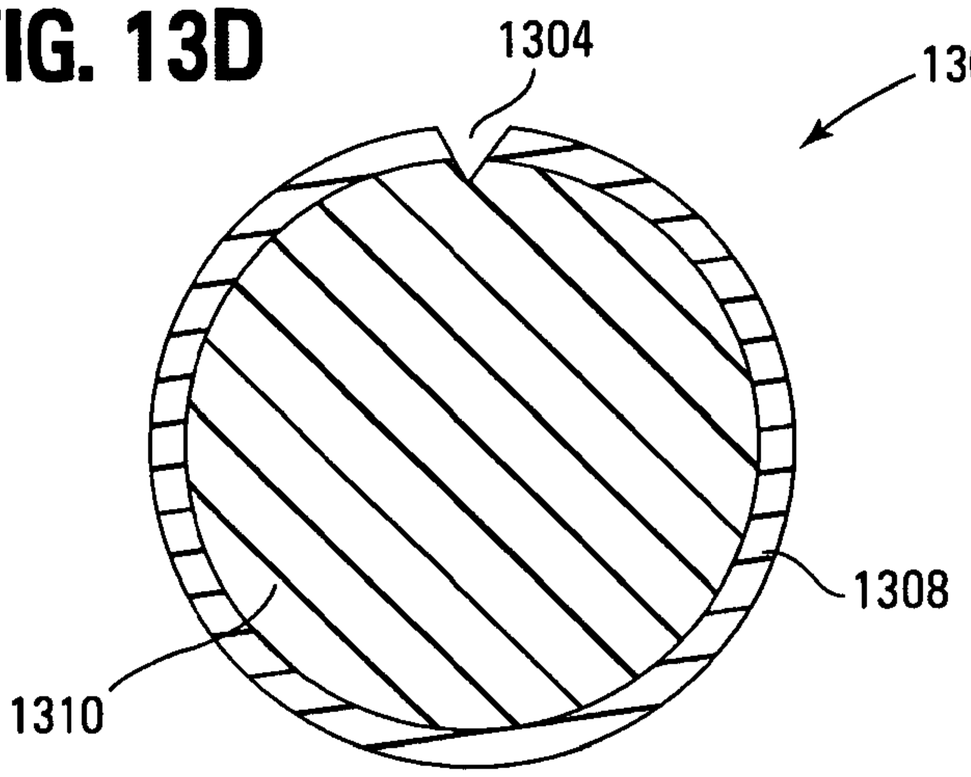


FIG. 13E

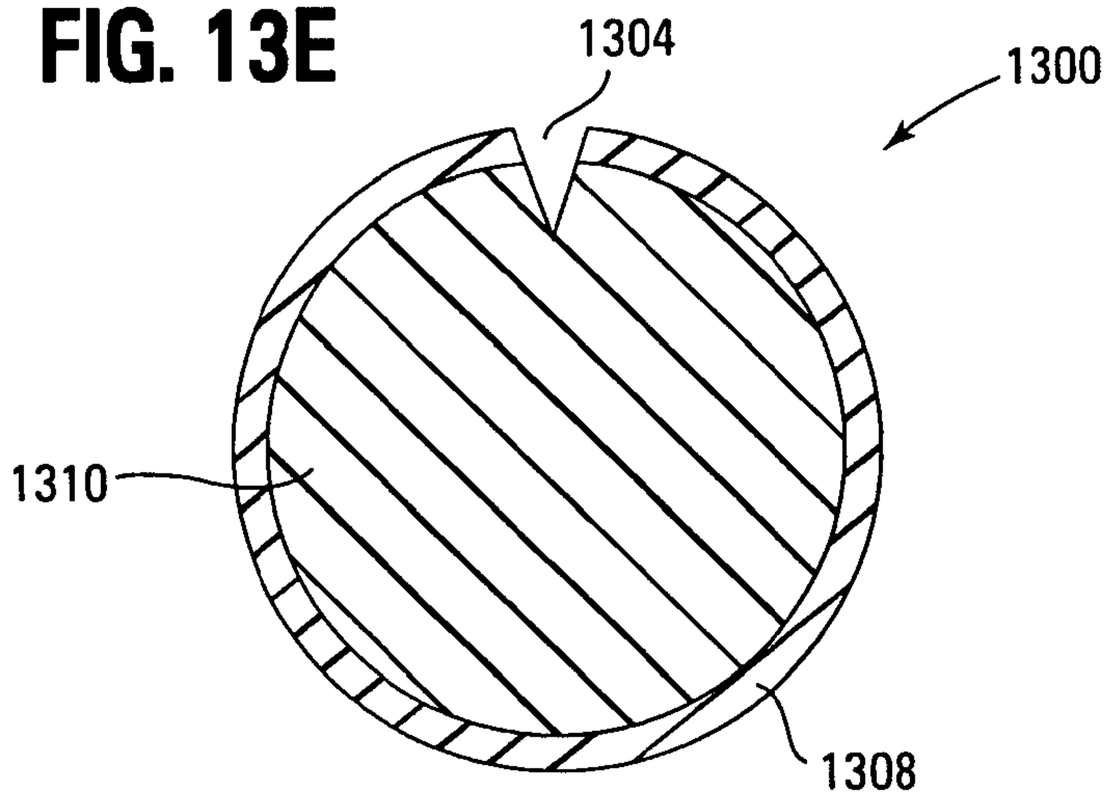
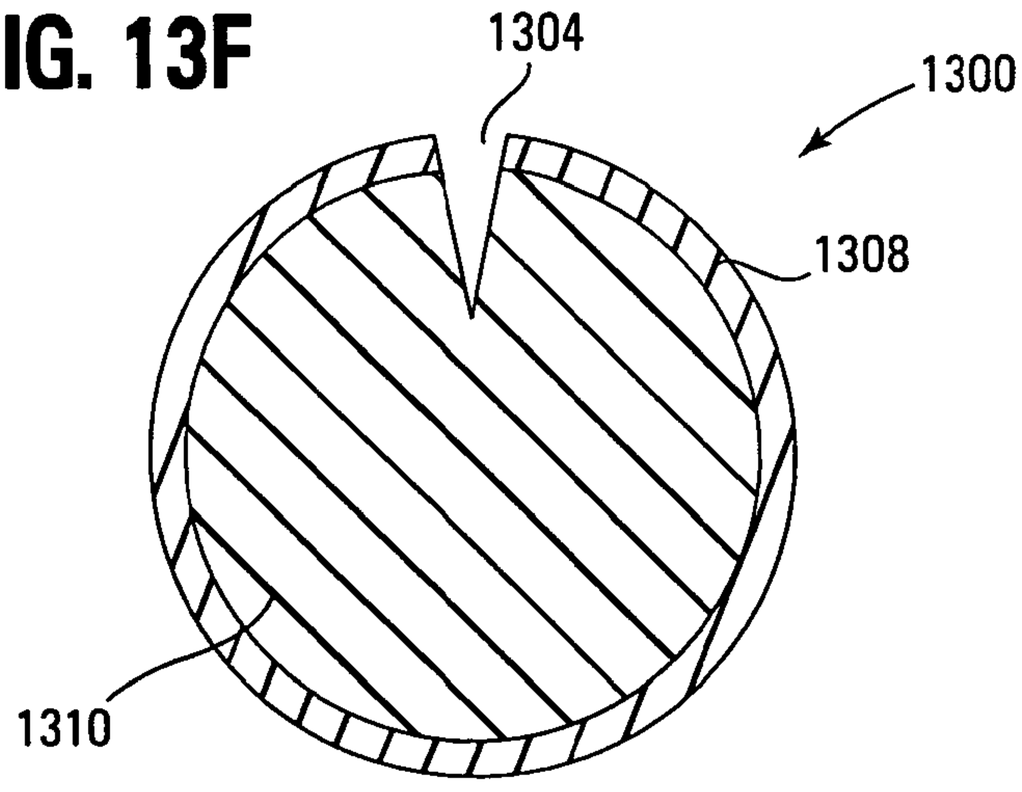


FIG. 13F



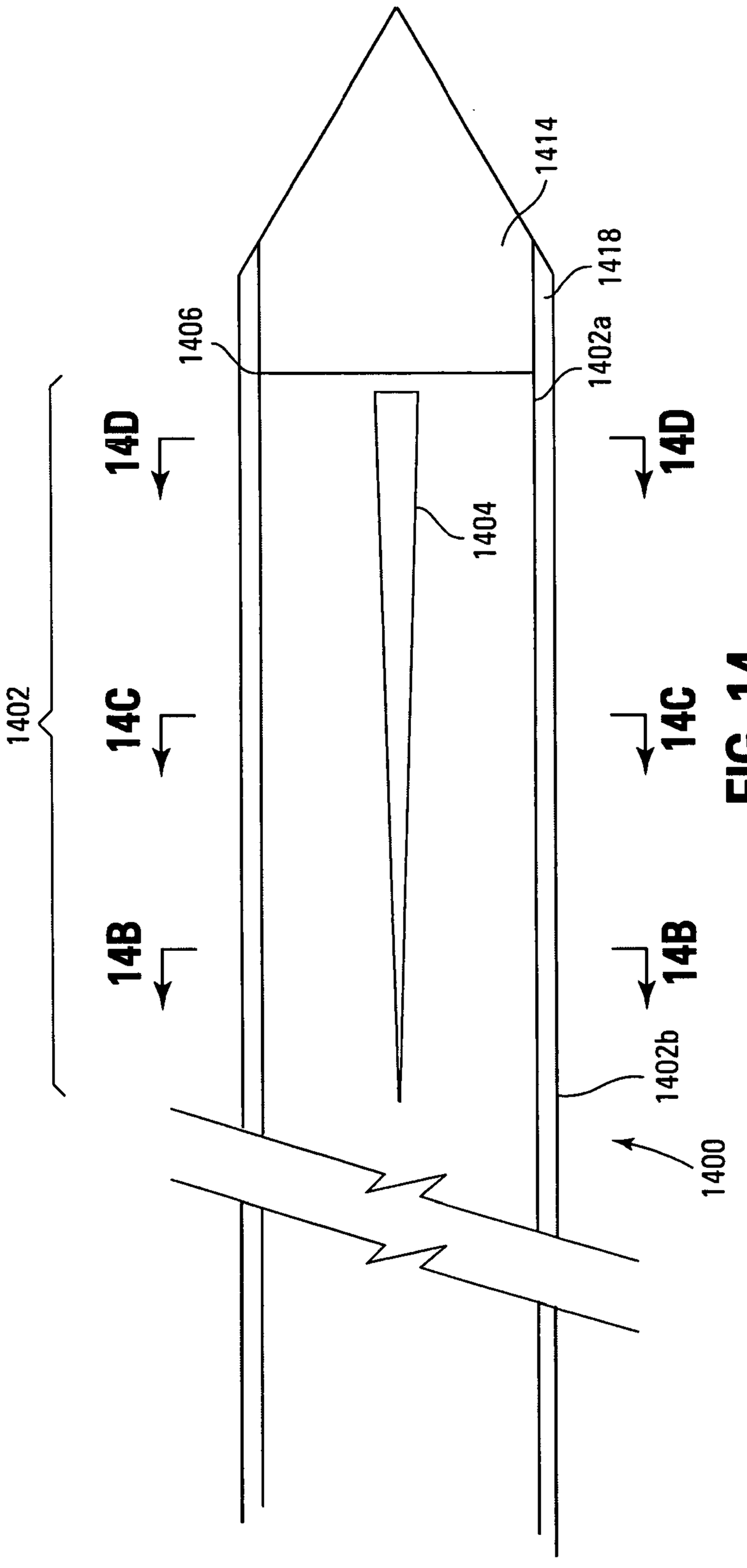

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FIG. 14

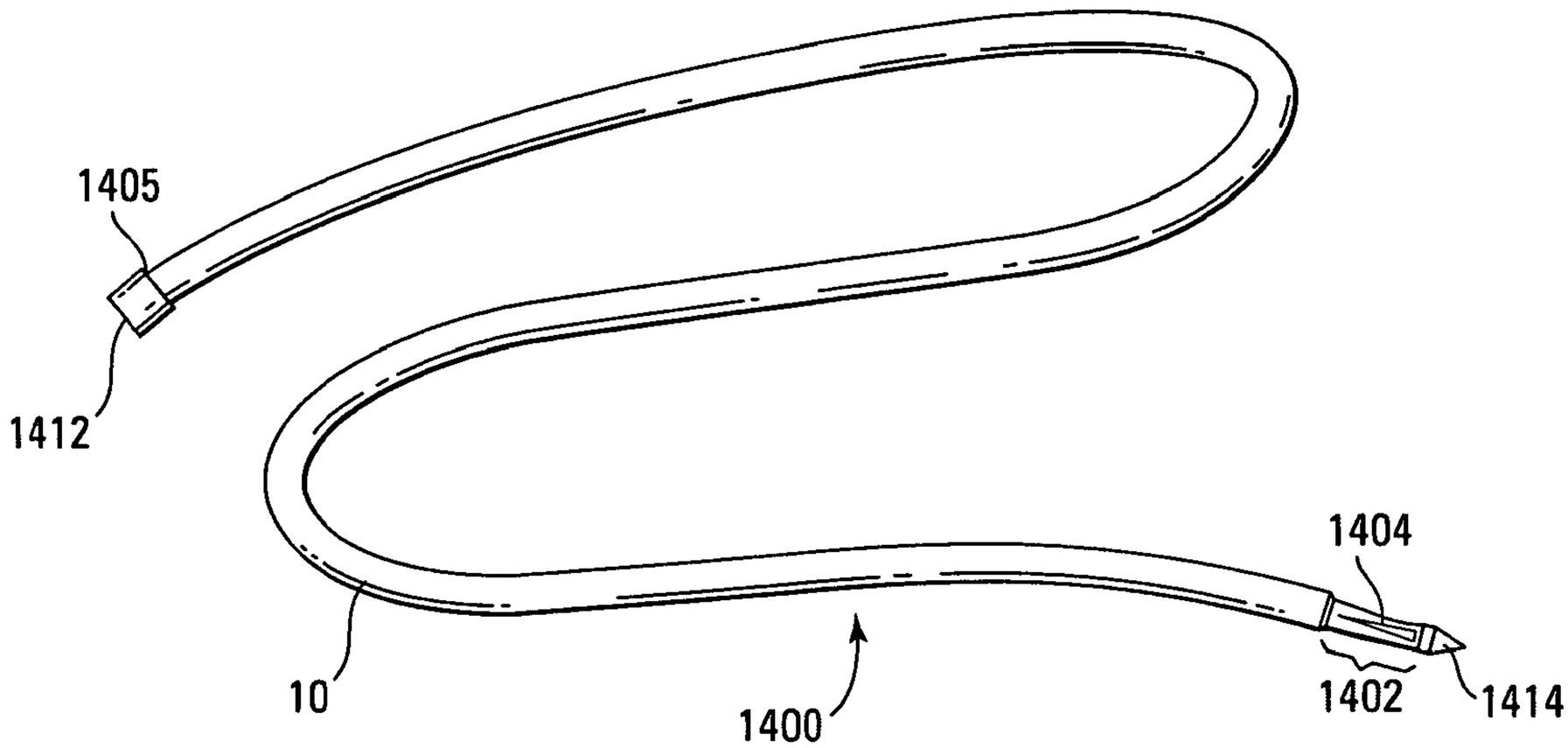


FIG. 14A

FIG. 14B

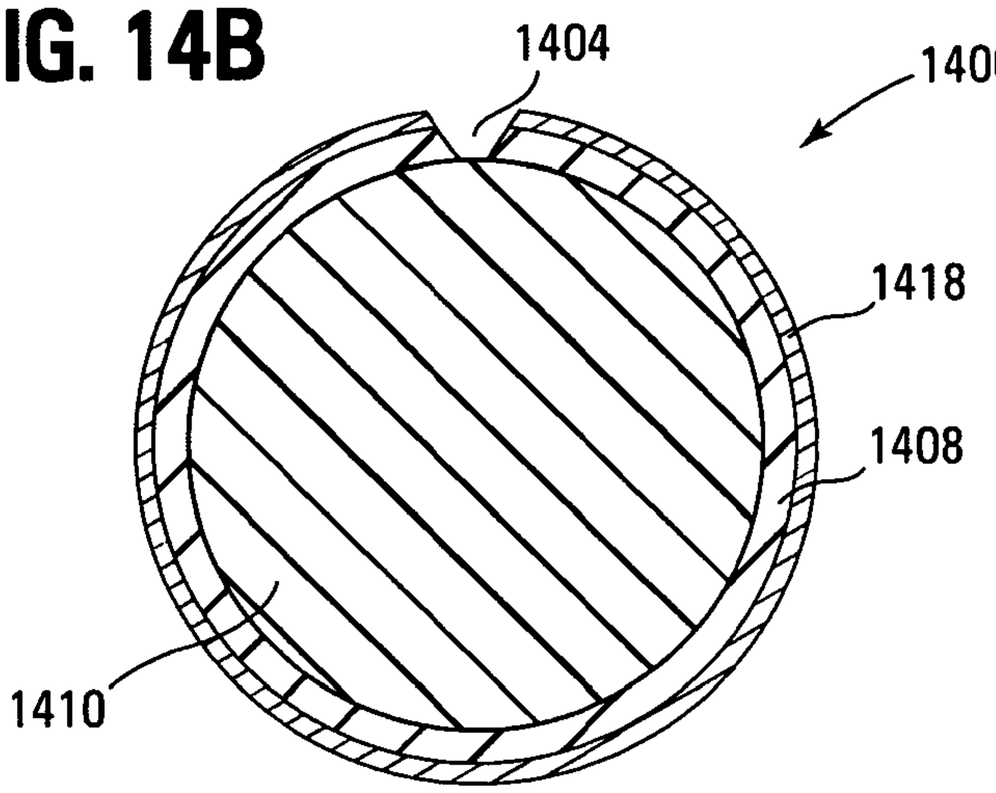


FIG. 14C

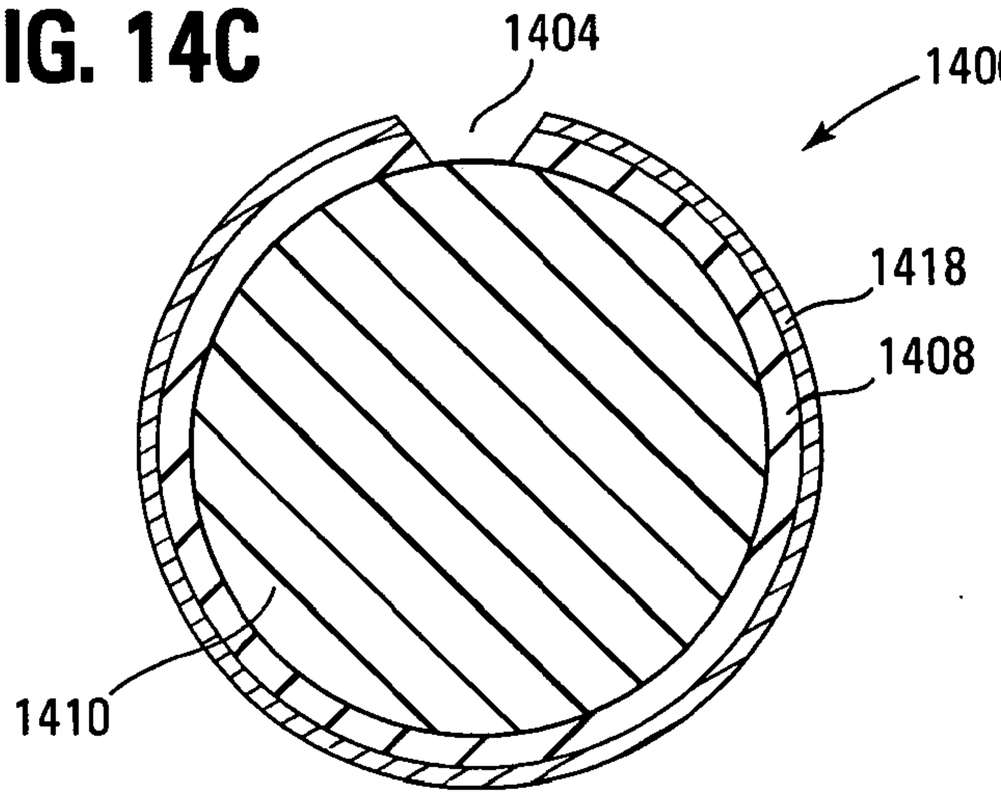
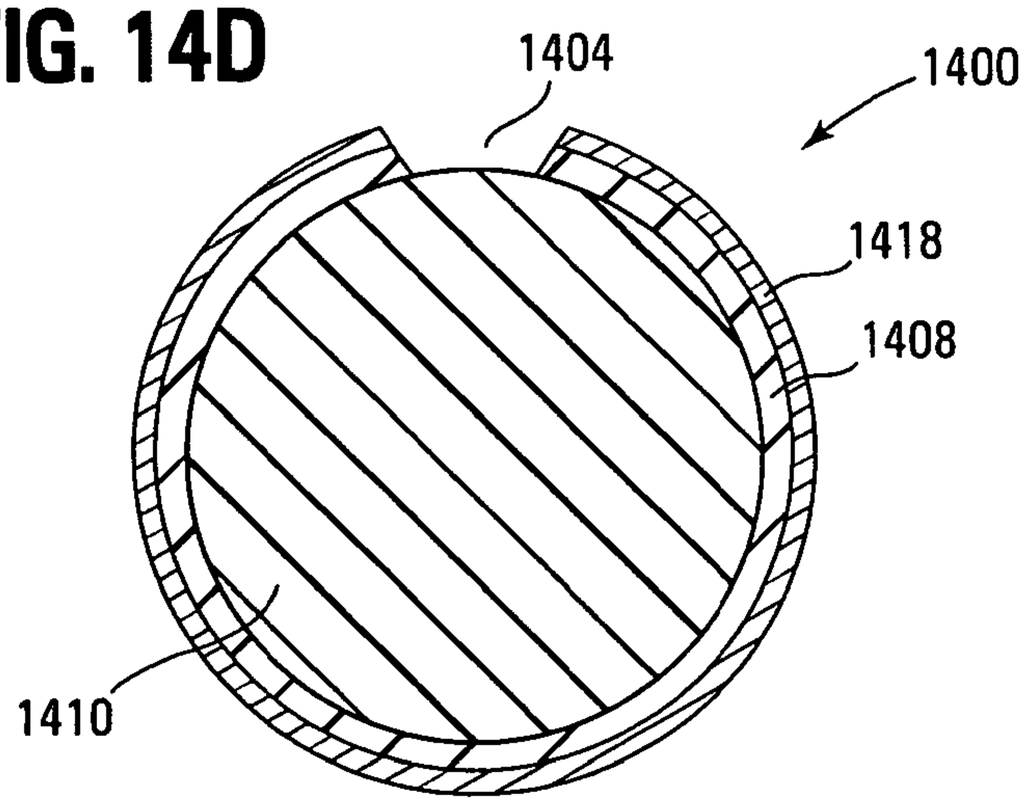


FIG. 14D



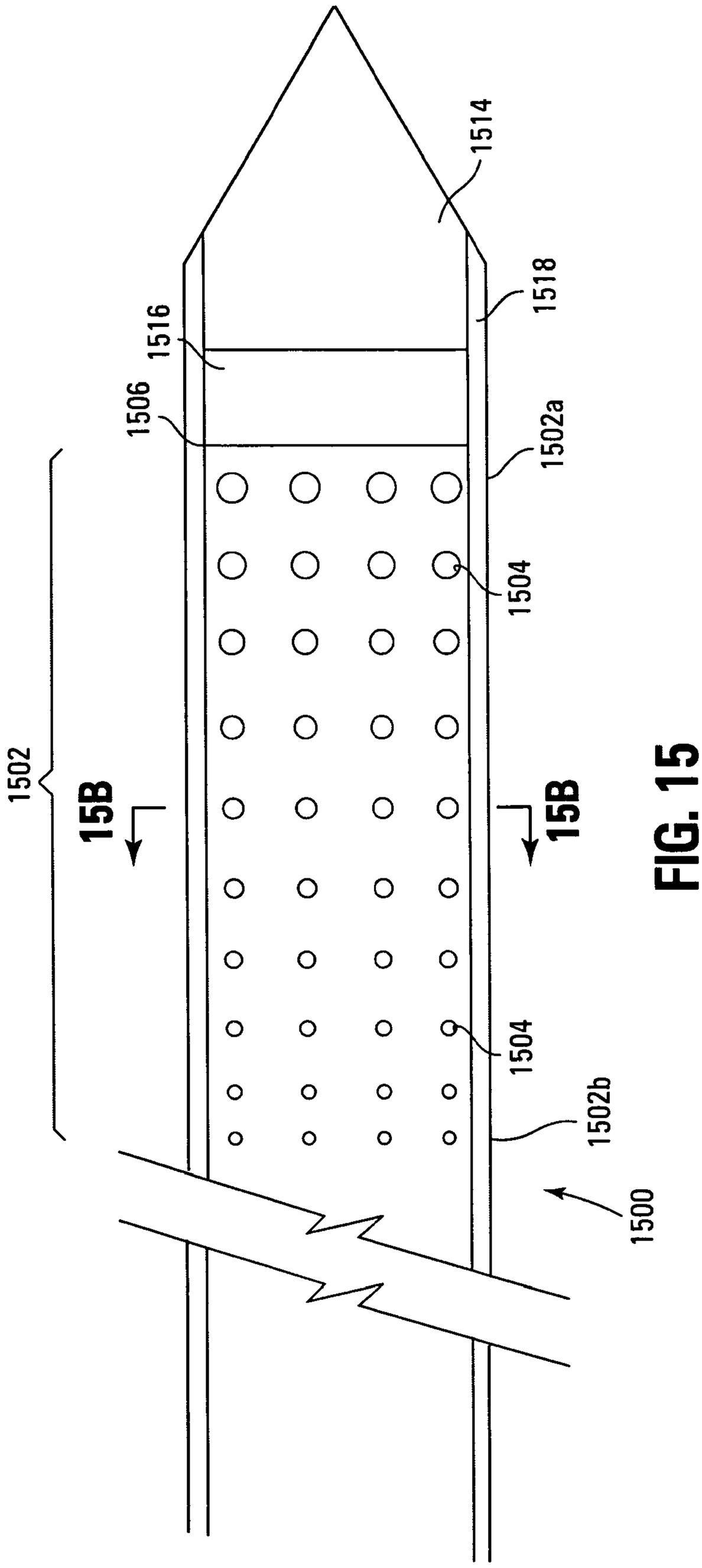


FIG. 15

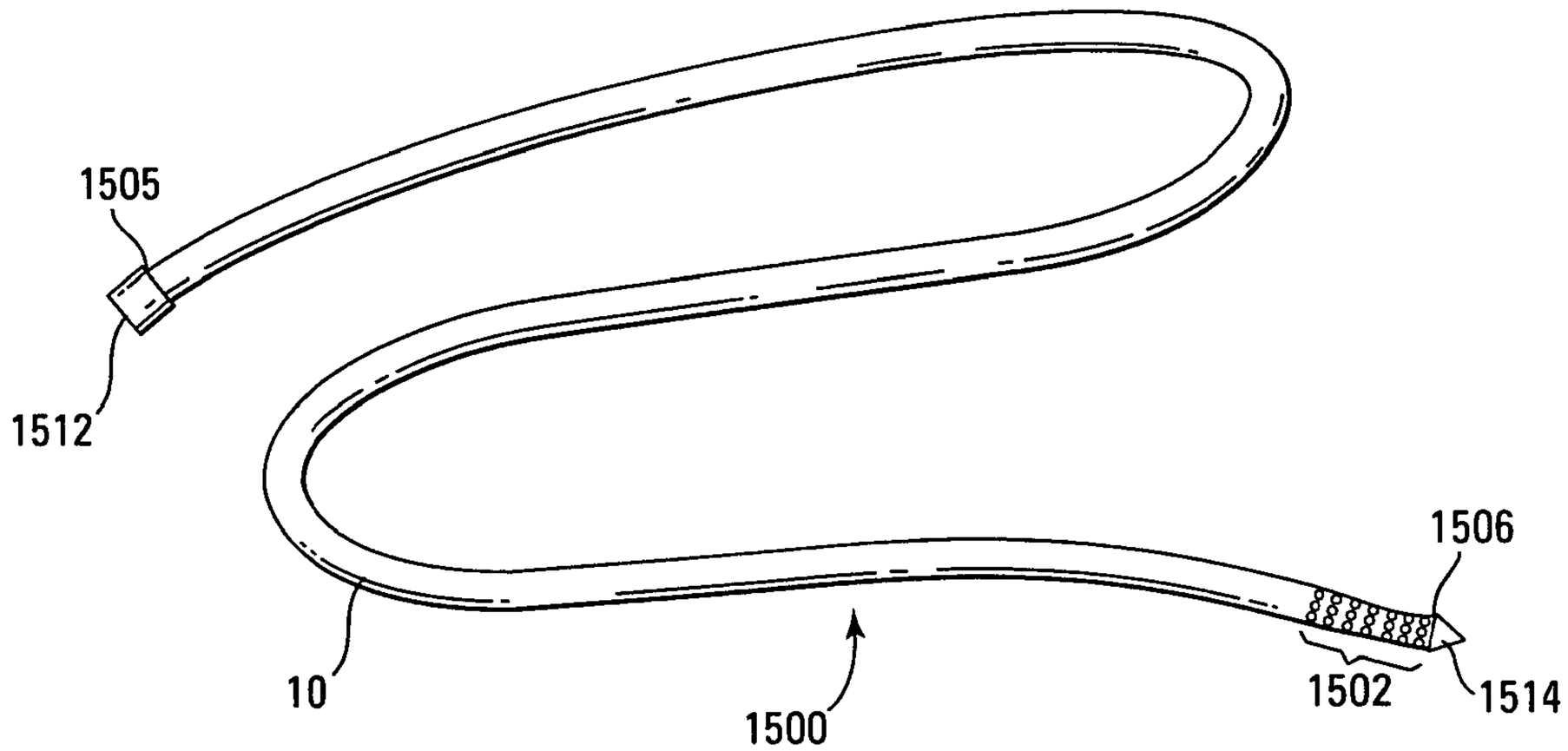
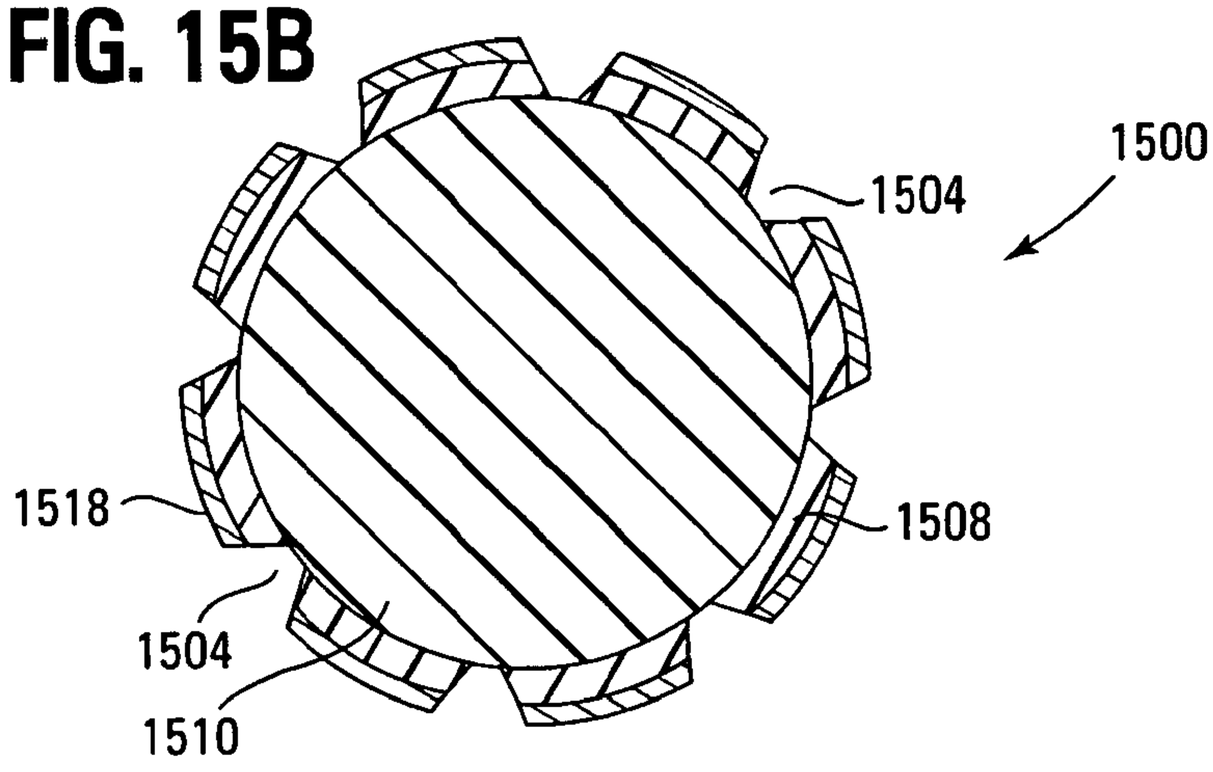


FIG. 15A

FIG. 15B



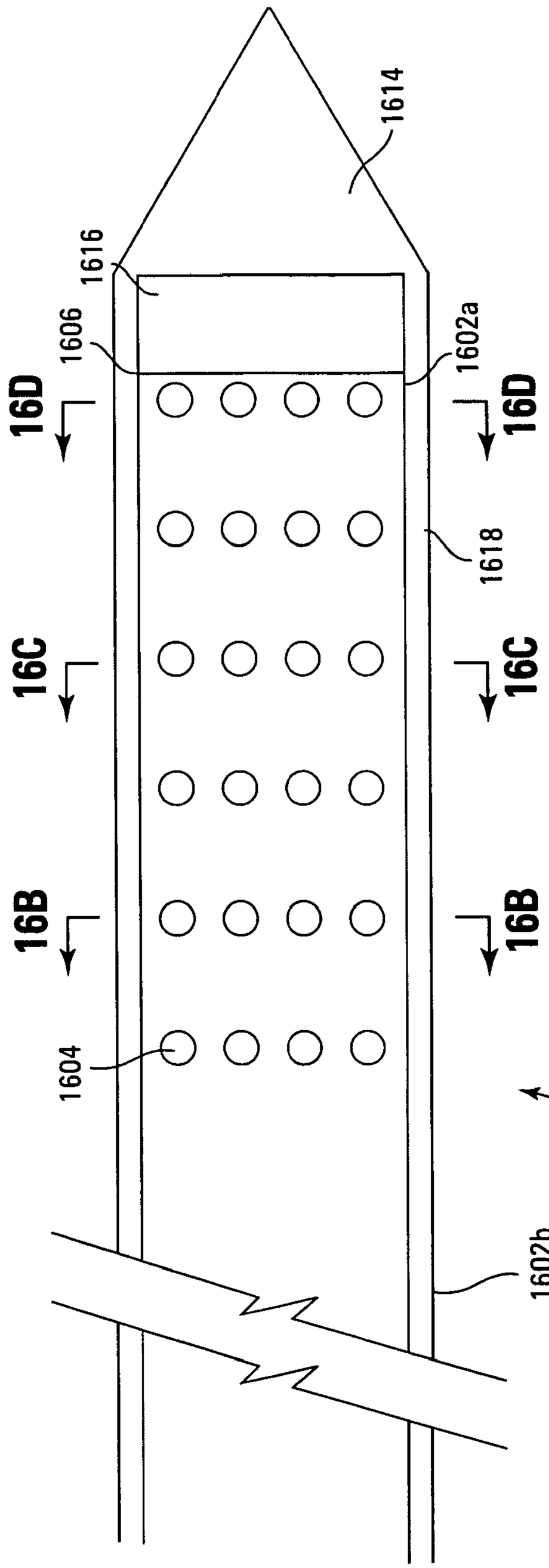

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FIG. 16

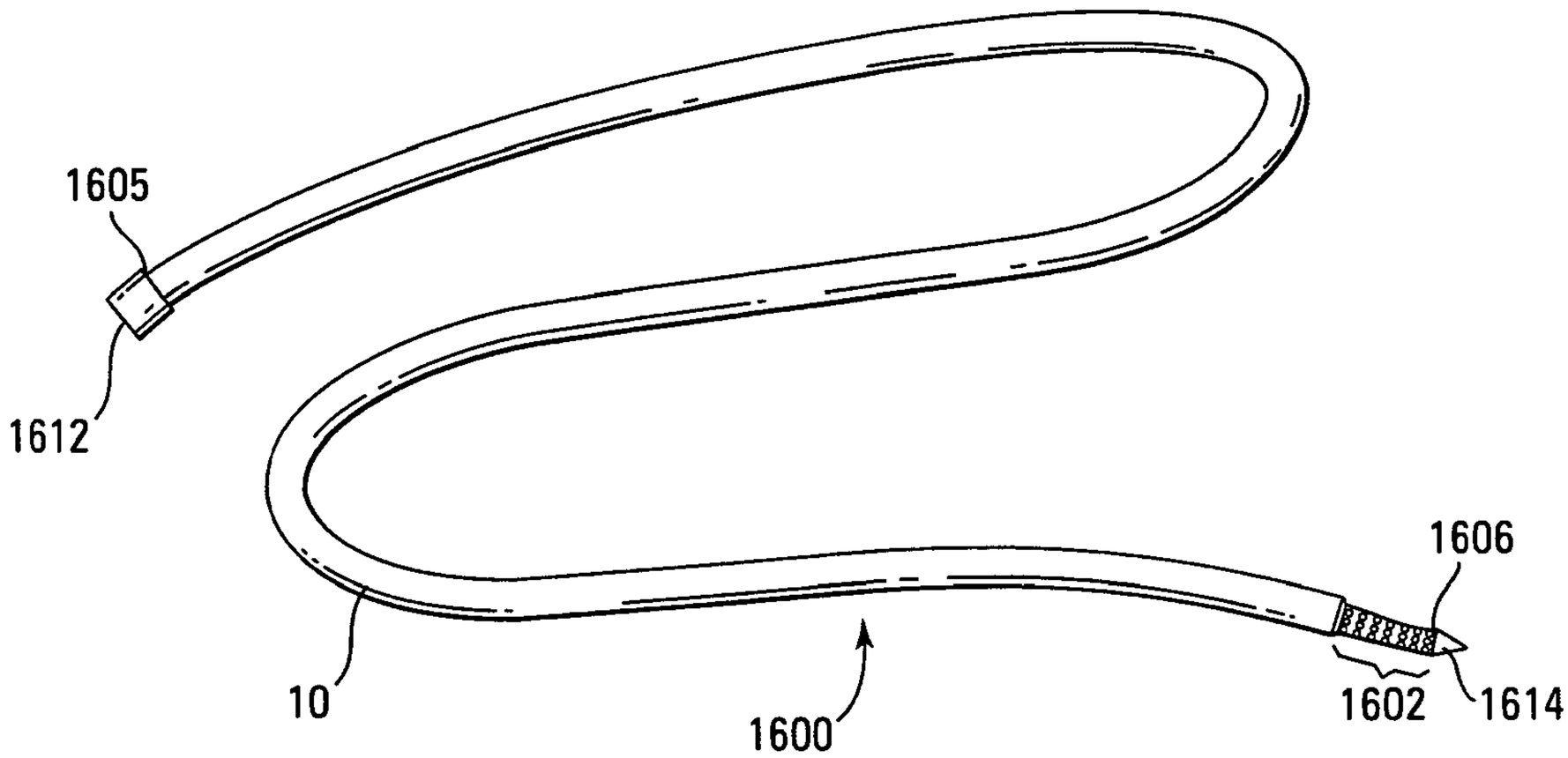


FIG. 16A

FIG. 16B

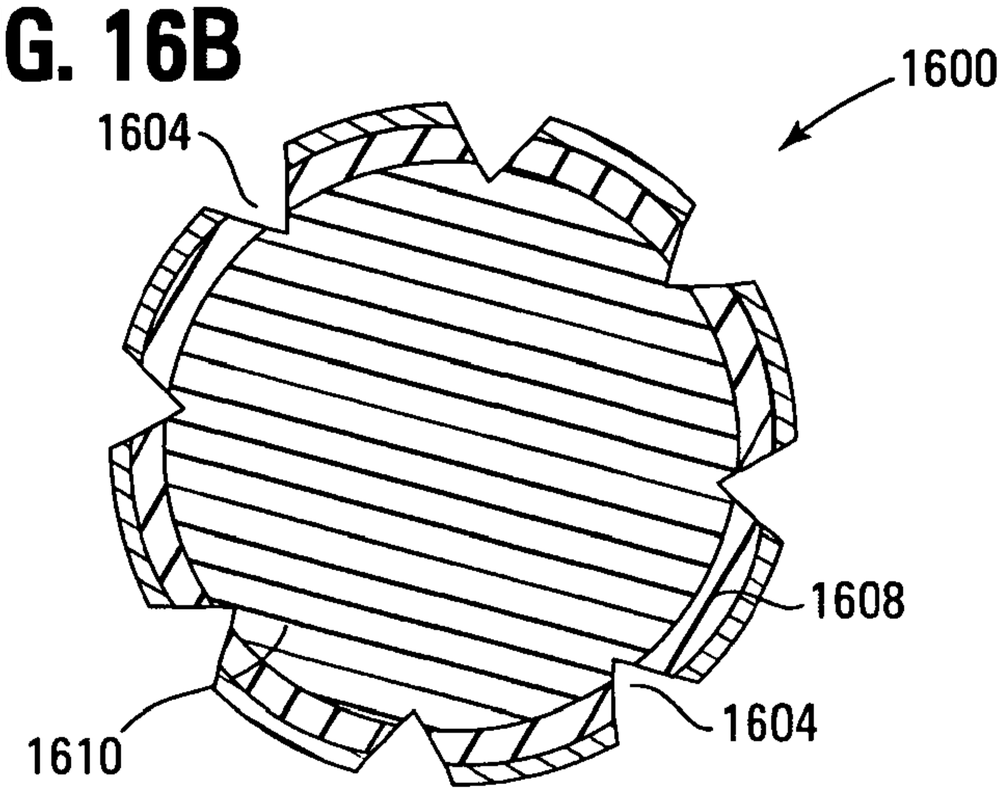


FIG. 16C

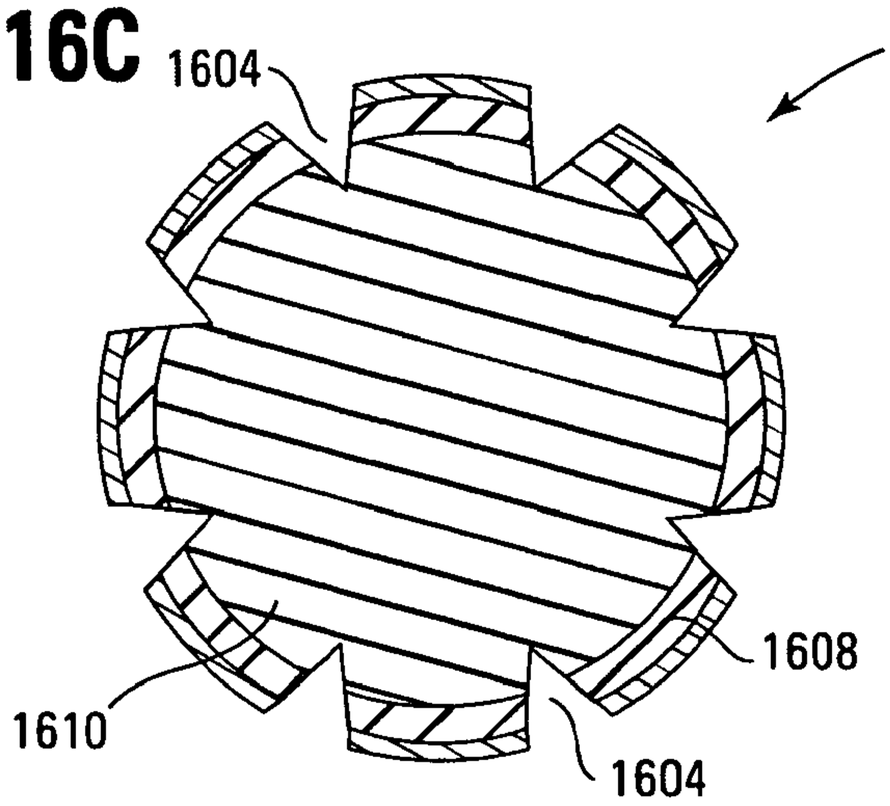
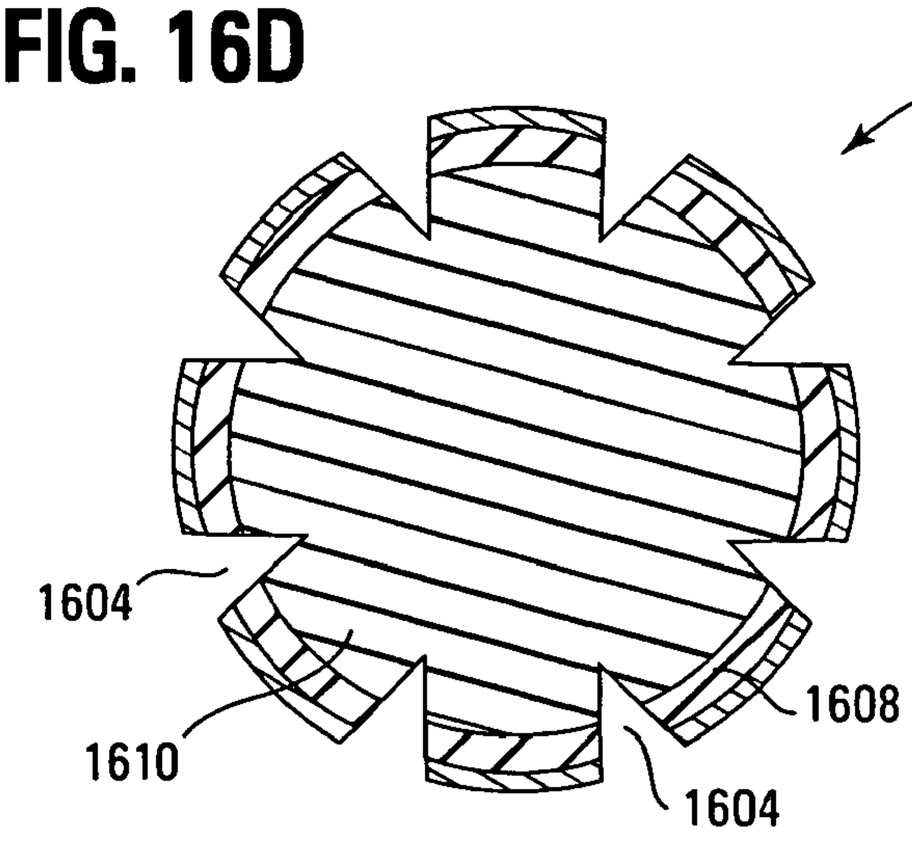


FIG. 16D



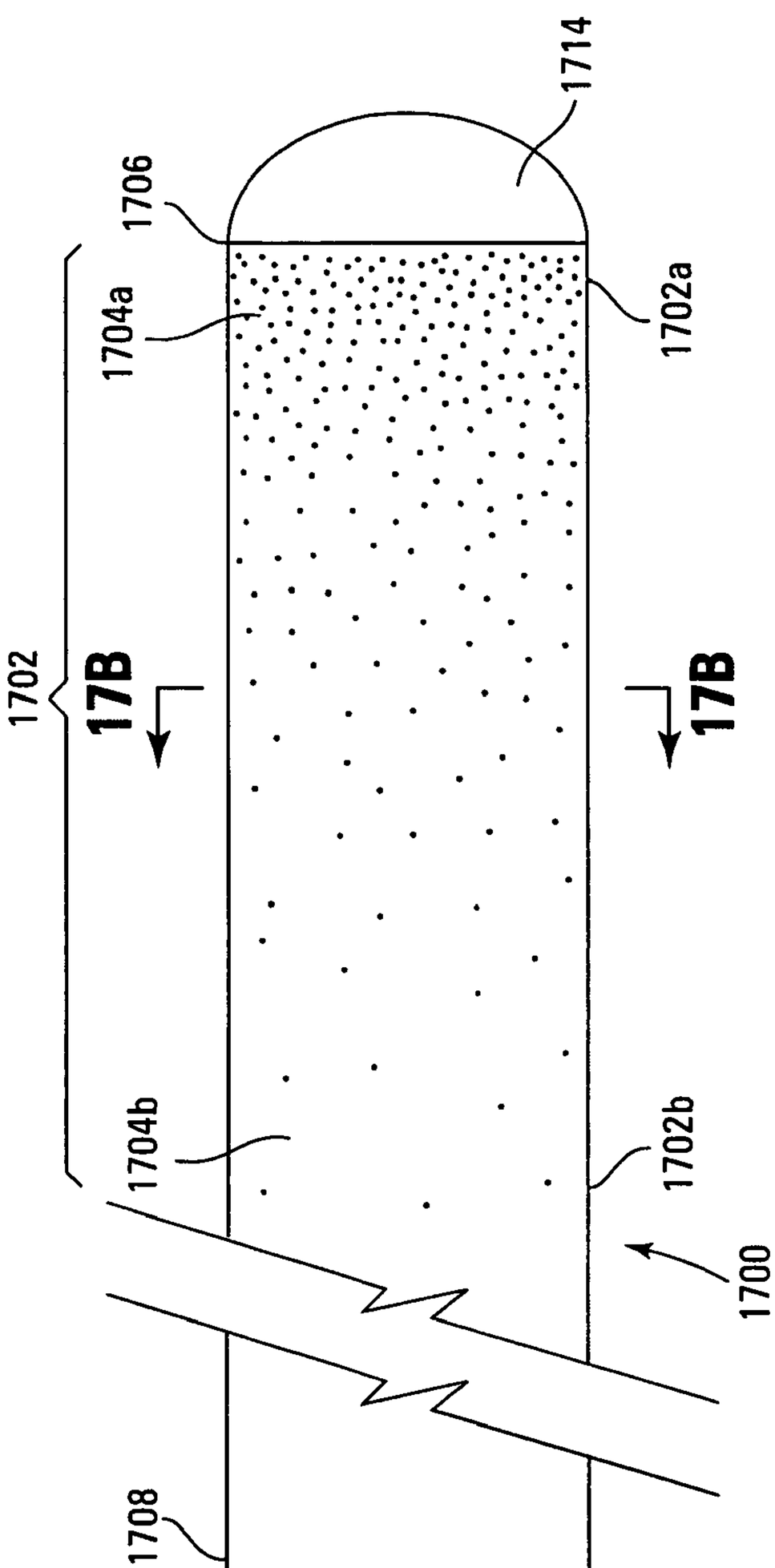


FIG. 17

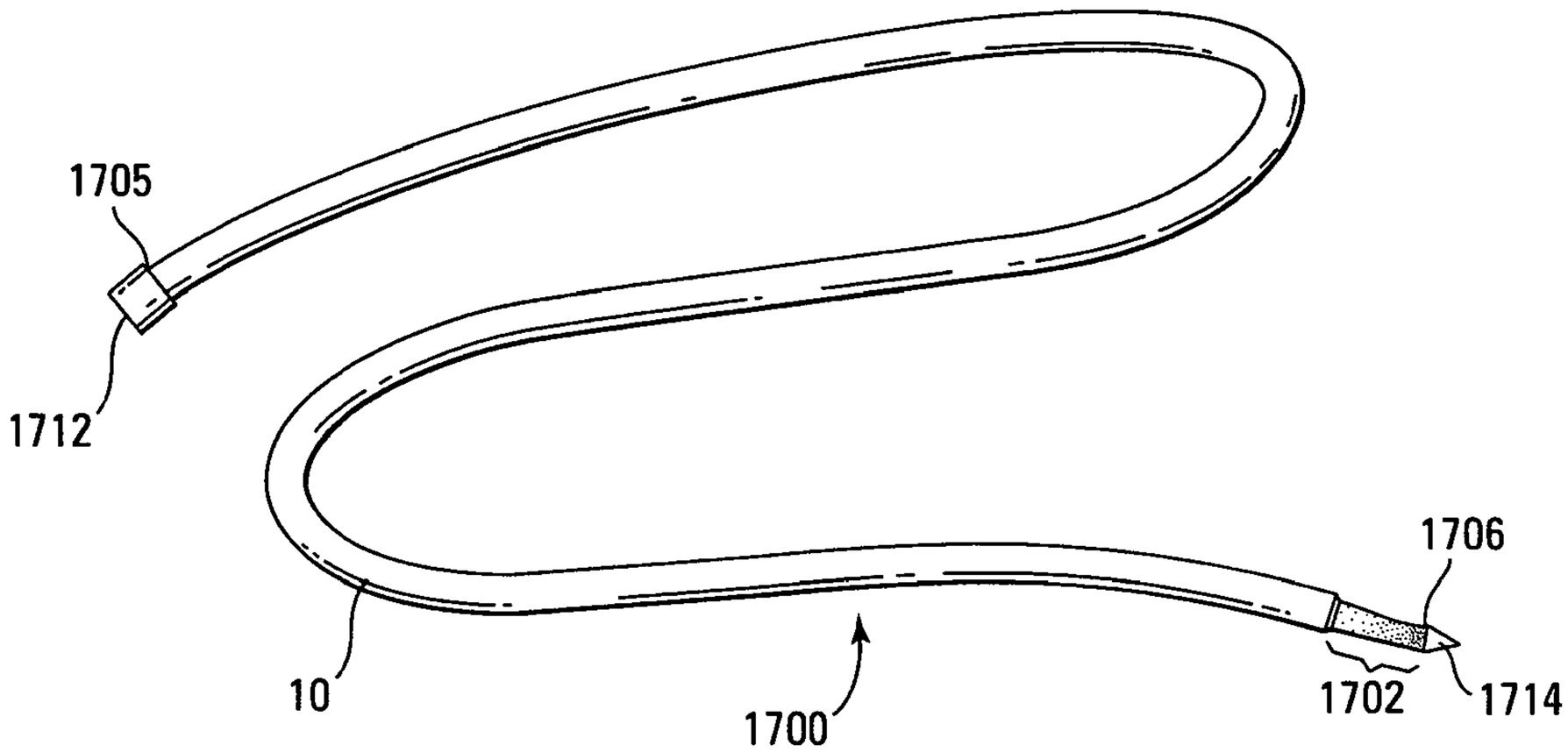
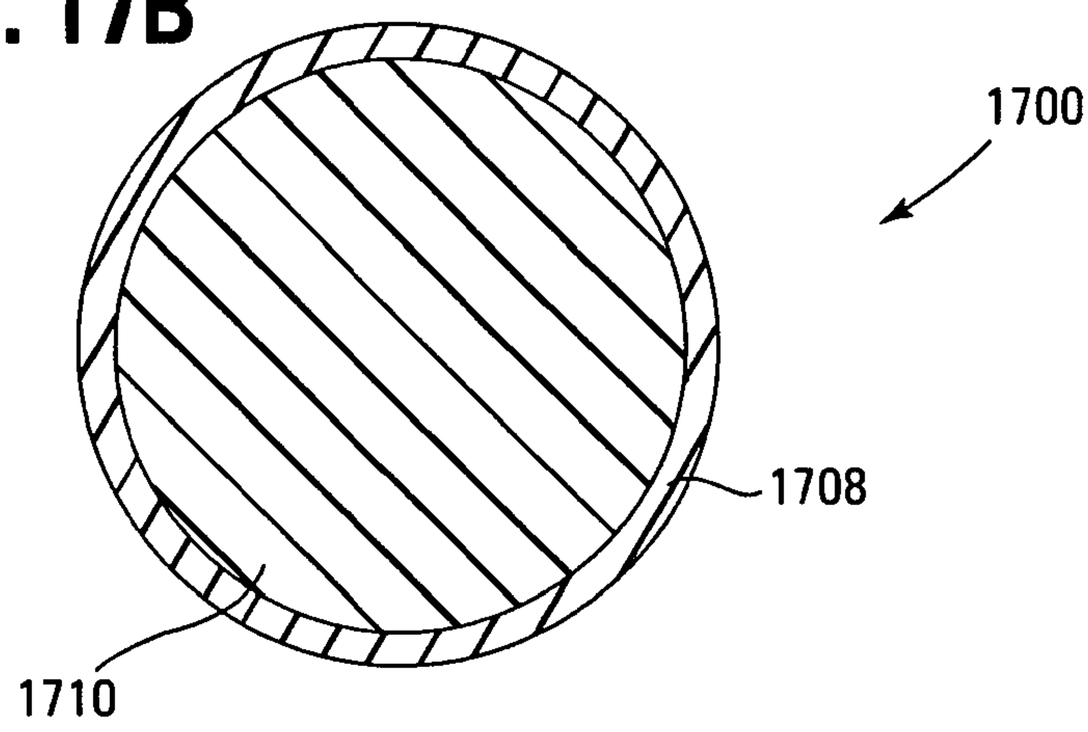
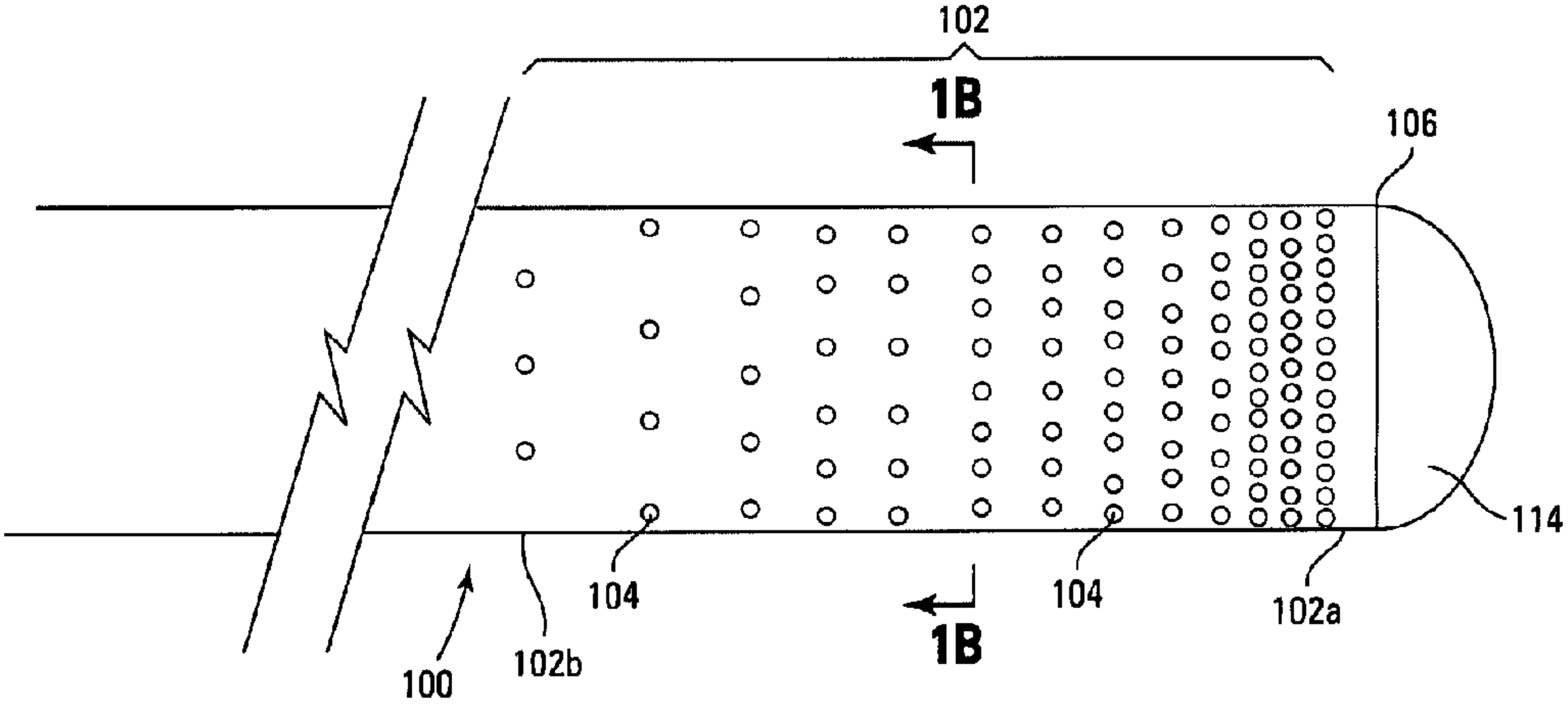


FIG. 17A

FIG. 17B

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