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Carter et al.

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(54) **MULTI-CONDUCTOR ROTARY CONNECTOR**

(71) Applicant: **RAMPART PRODUCTS LLC**, Houston, TX (US)

(72) Inventors: **Sean W Carter**, Houston, TX (US); **Michael A Czuppon**, Houston, TX (US); **Edward J Beshoory**, Houston, TX (US)

(73) Assignee: **RAMPART PRODUCTS LLC**, Houston, TX (US)

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H01R 39/64 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC ***H01R 13/187*** (2013.01); ***H01R 13/10*** (2013.01); ***H01R 13/17*** (2013.01); ***H01R 39/64*** (2013.01)

(58) **Field of Classification Search**
CPC H01R 13/187; H01R 39/64; H01R 13/10; H01R 13/17; H01R 24/58; H01R 13/111; H01R 39/00; H01R 24/38
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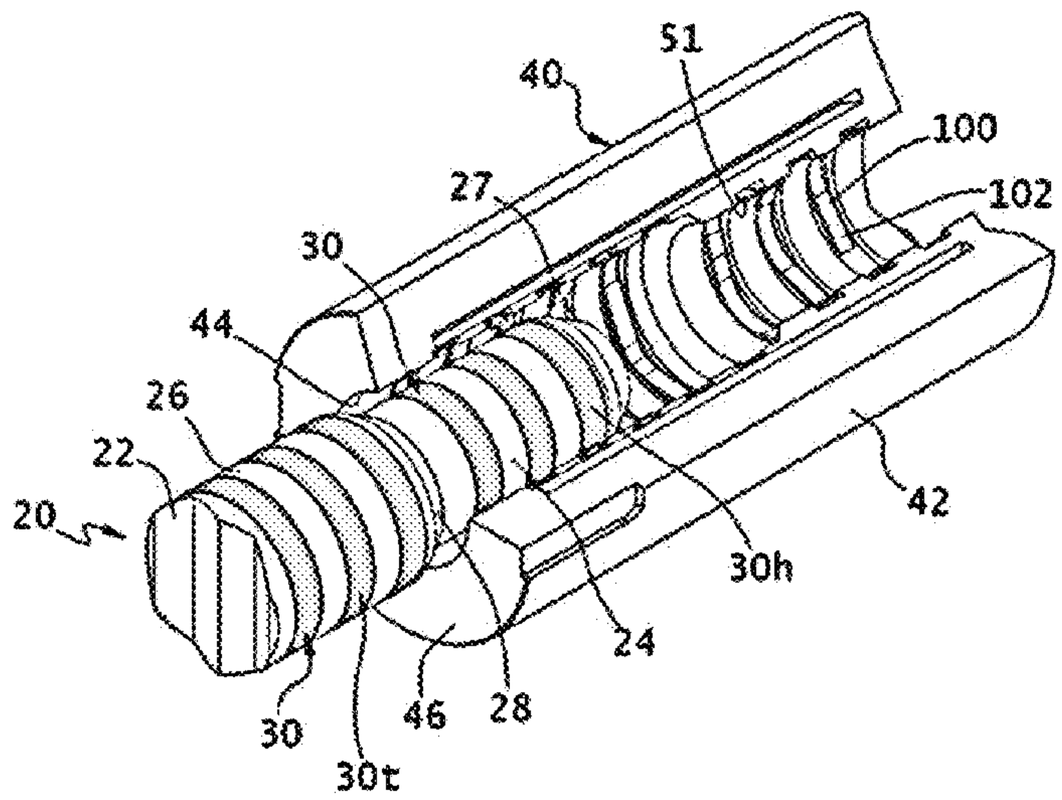
Primary Examiner — Travis S Chambers
(74) *Attorney, Agent, or Firm* — Bracewell LLP; Douglas W. Rommelmann

(57) **ABSTRACT**

An electrical connector comprising a plug arranged and designed to connect to a receptacle. The plug includes an electrically-insulating body, a conductor ring, and a conductive member connected to the plug conductor ring. The receptacle includes an electrically-insulating body, a conductor ring having an axial inner bore and an annular groove facing radially inward, a conductive member connected to the receptacle conductor ring, and an electrically-conductive contact having a generally annular profile, at least a portion of the electrically-conductive contact received in and contacting the annular groove and at least a portion of the electrically-conductive contact not received in the annular groove. Upon insertion of the plug into the receptacle and substantially radially aligning the plug and receptacle conductor rings, the electrically-conductive contact is elastically deformed and provides electrical contact between the plug conductor ring and the receptacle conductor ring.

25 Claims, 14 Drawing Sheets



(51) **Int. Cl.**
H01R 13/10 (2006.01)
H01R 13/17 (2006.01)

(58) **Field of Classification Search**
USPC 439/25, 675
See application file for complete search history.

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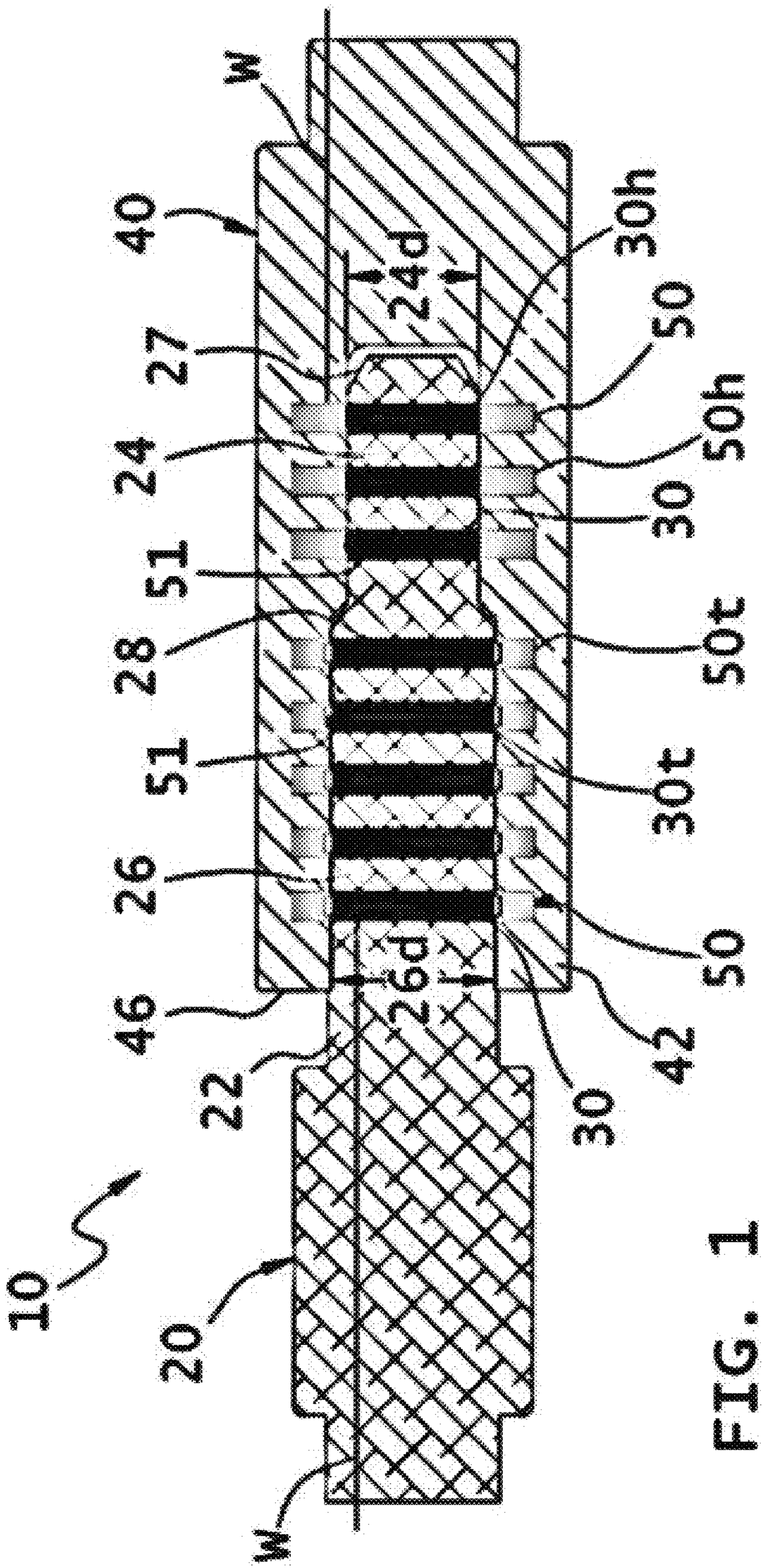

FIG. 1

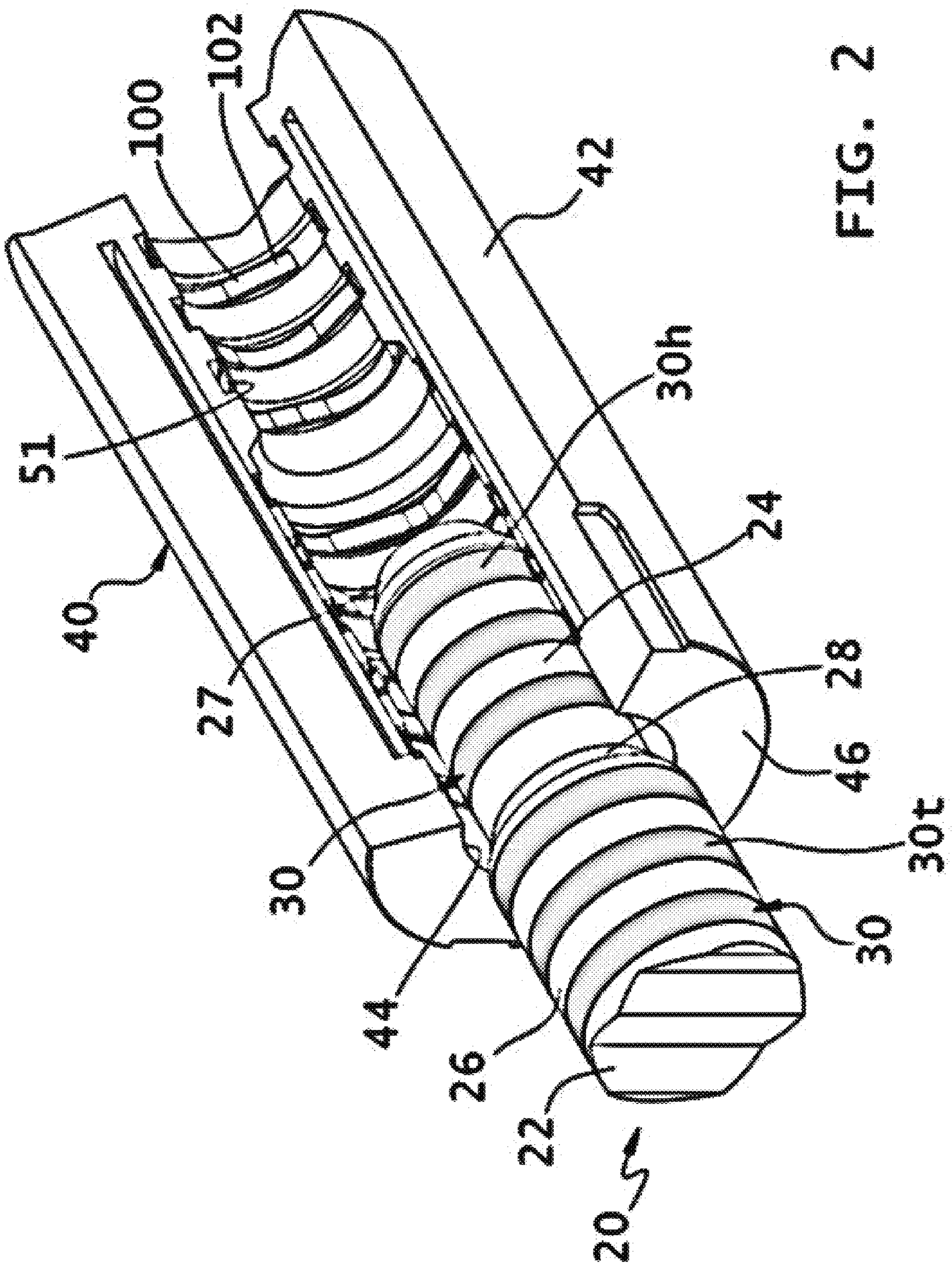

FIG. 2

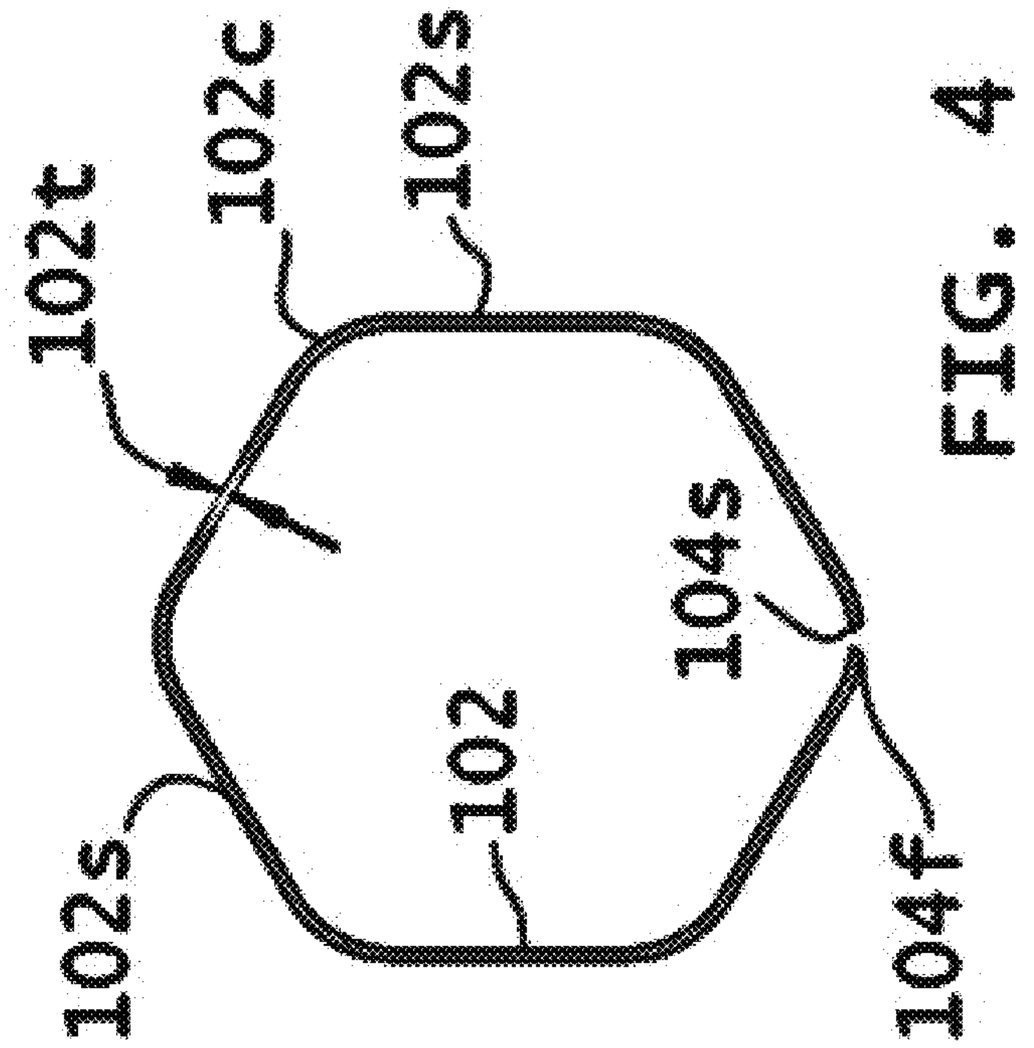

FIG. 4

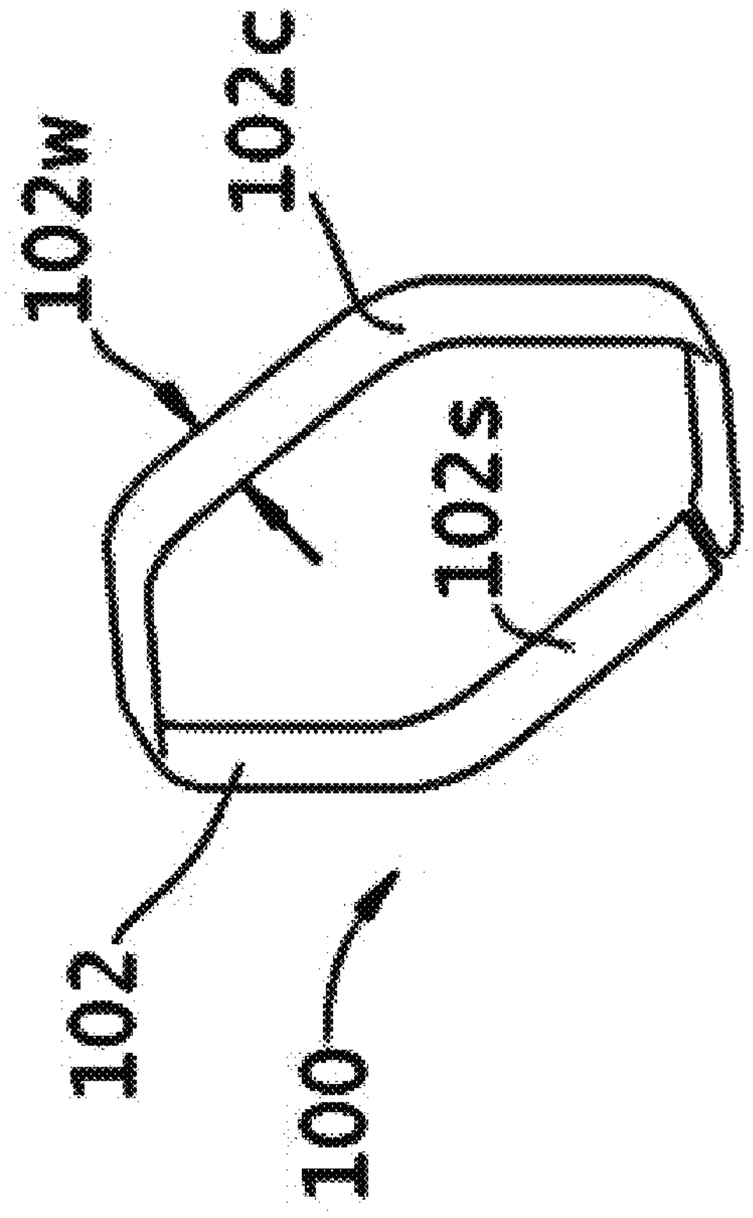

FIG. 3

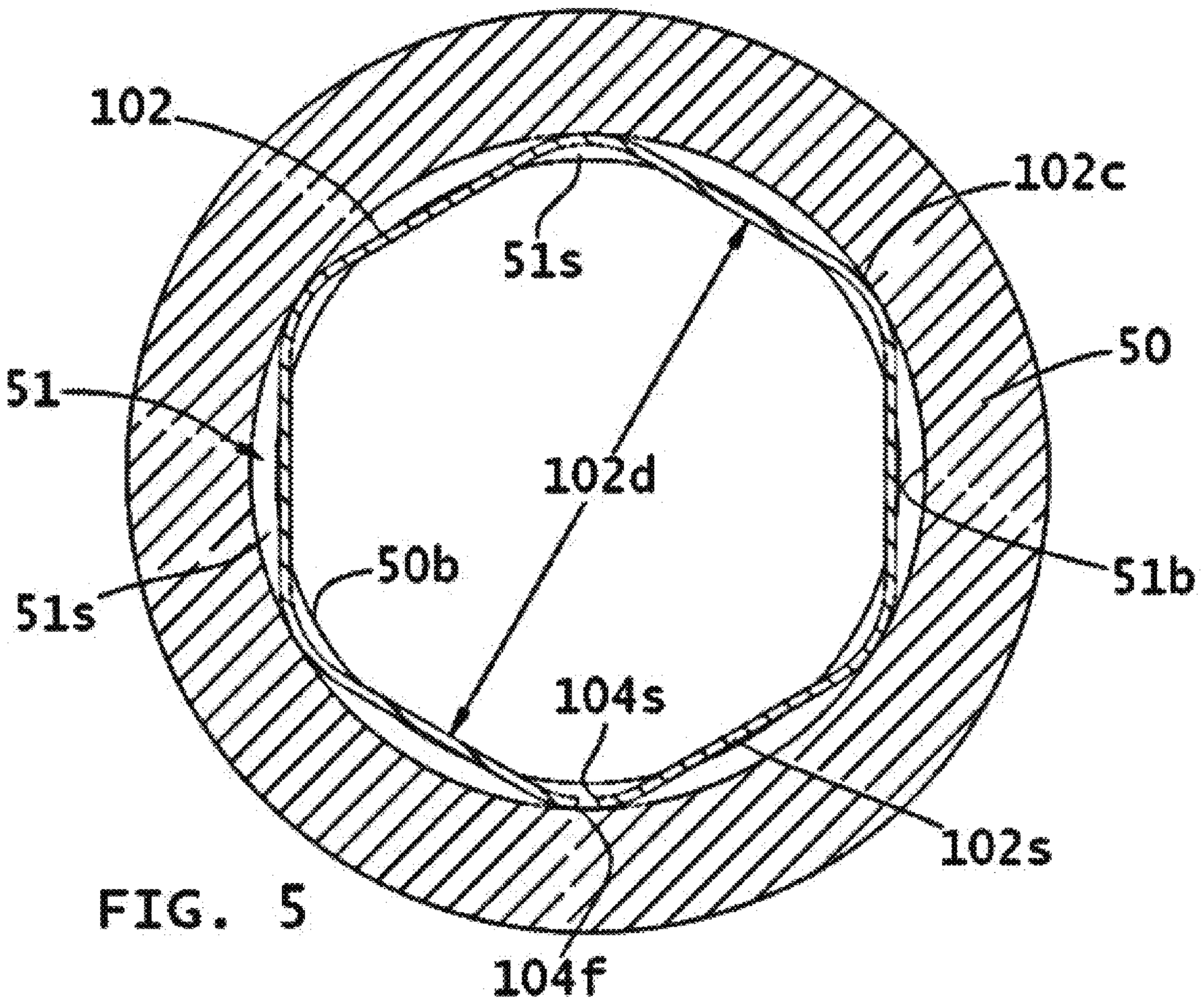

FIG. 5

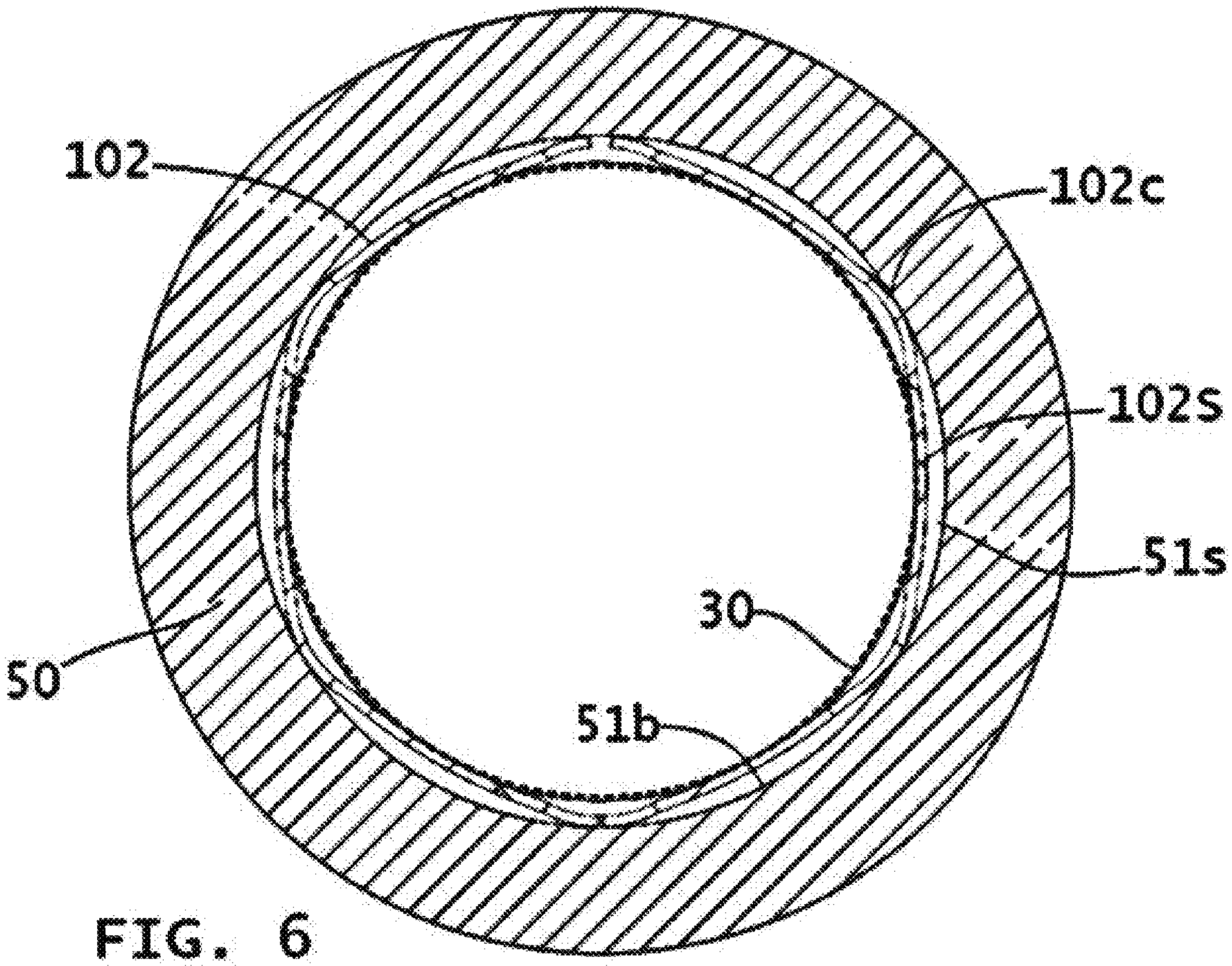

FIG. 6

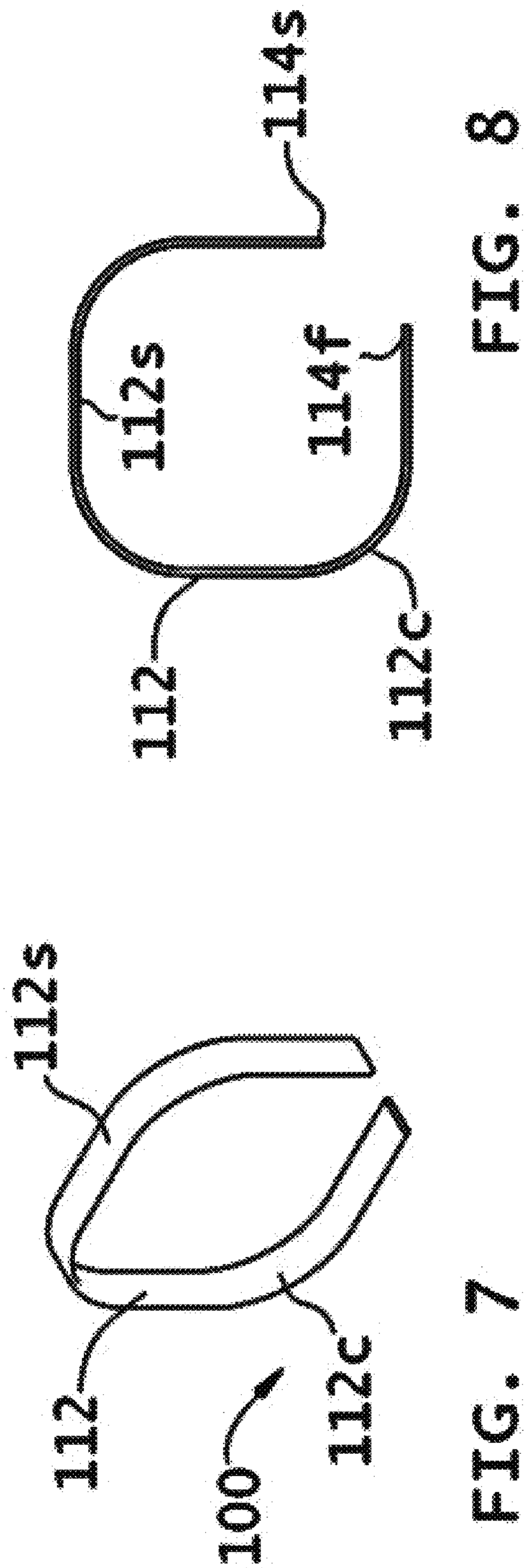

FIG. 8

FIG. 7

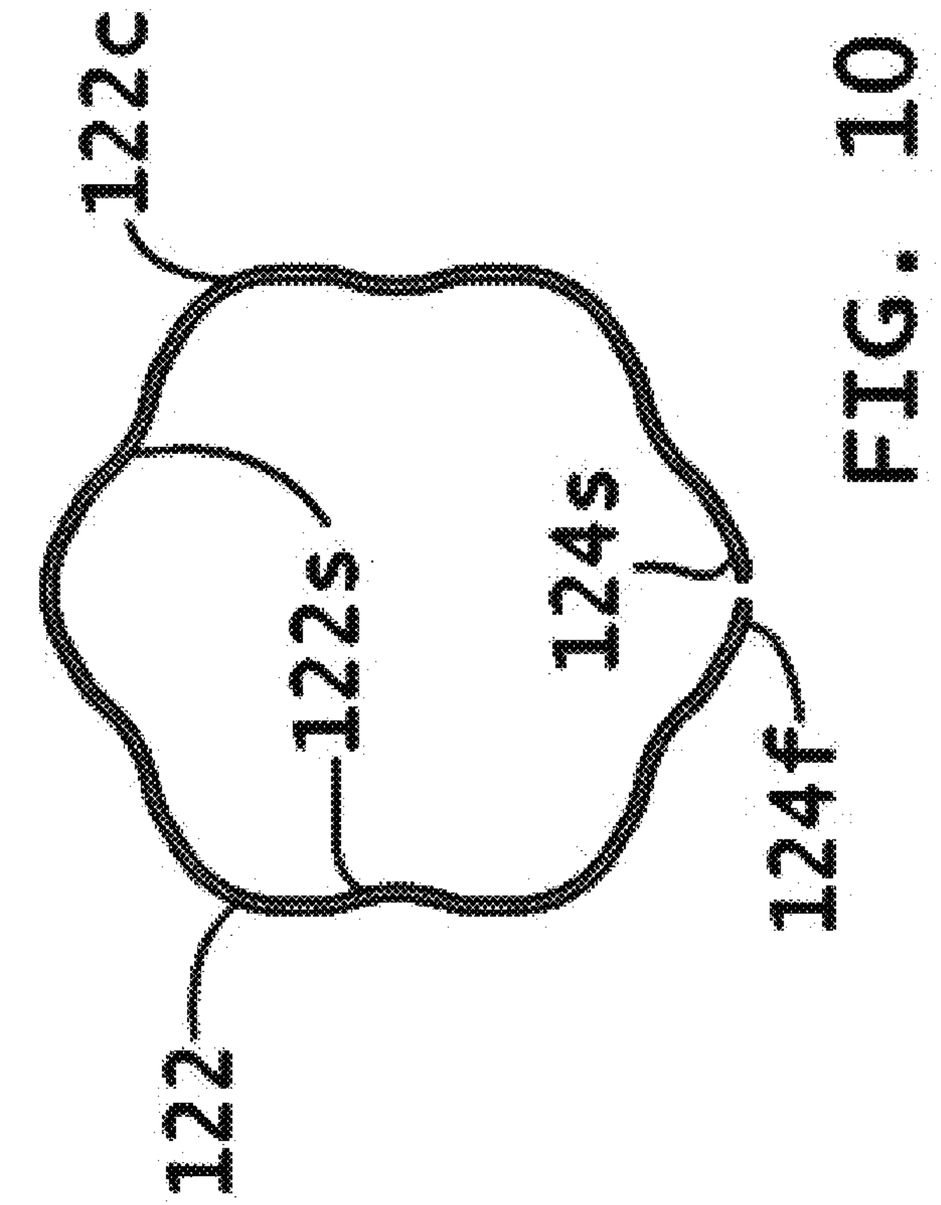

FIG. 10

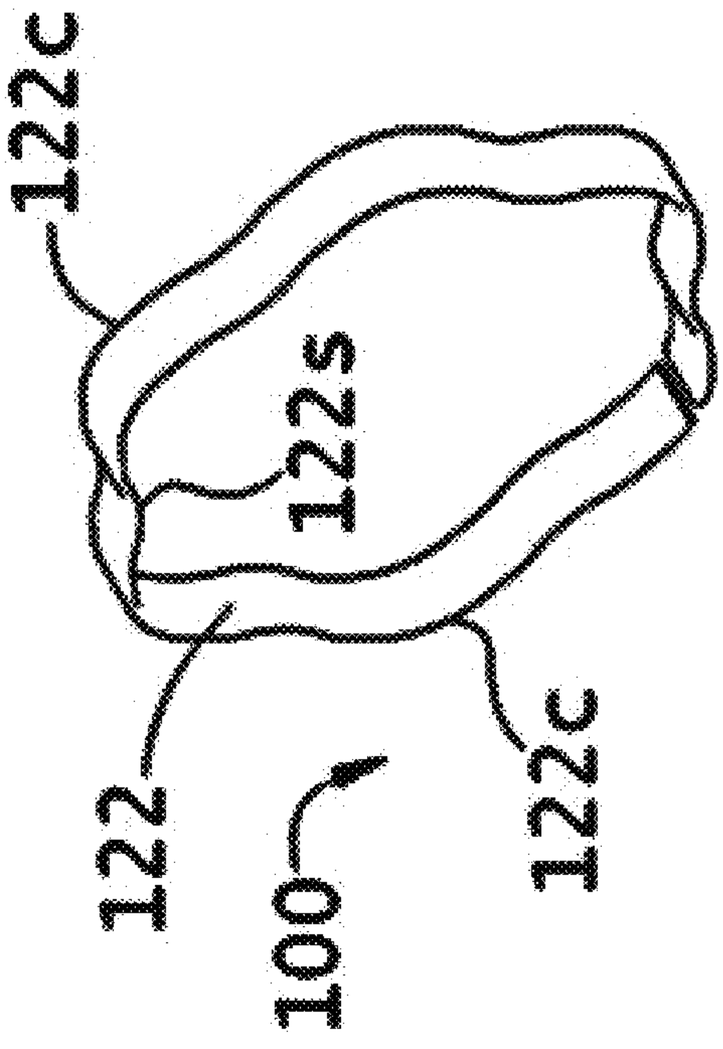

FIG. 9

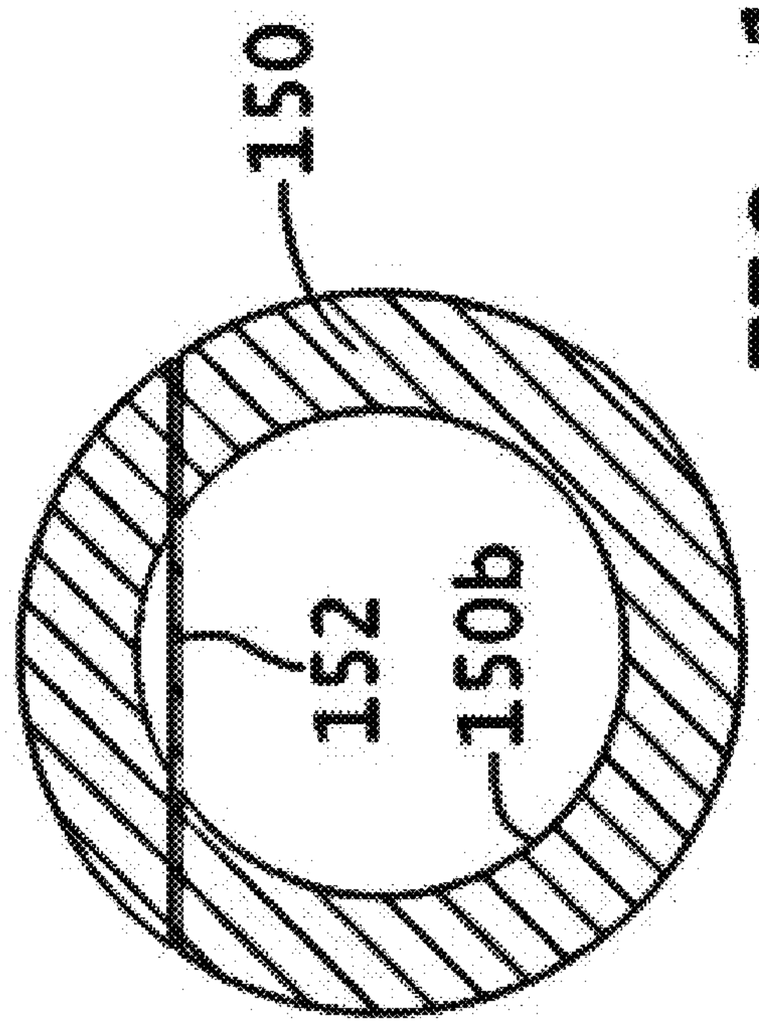

FIG. 12

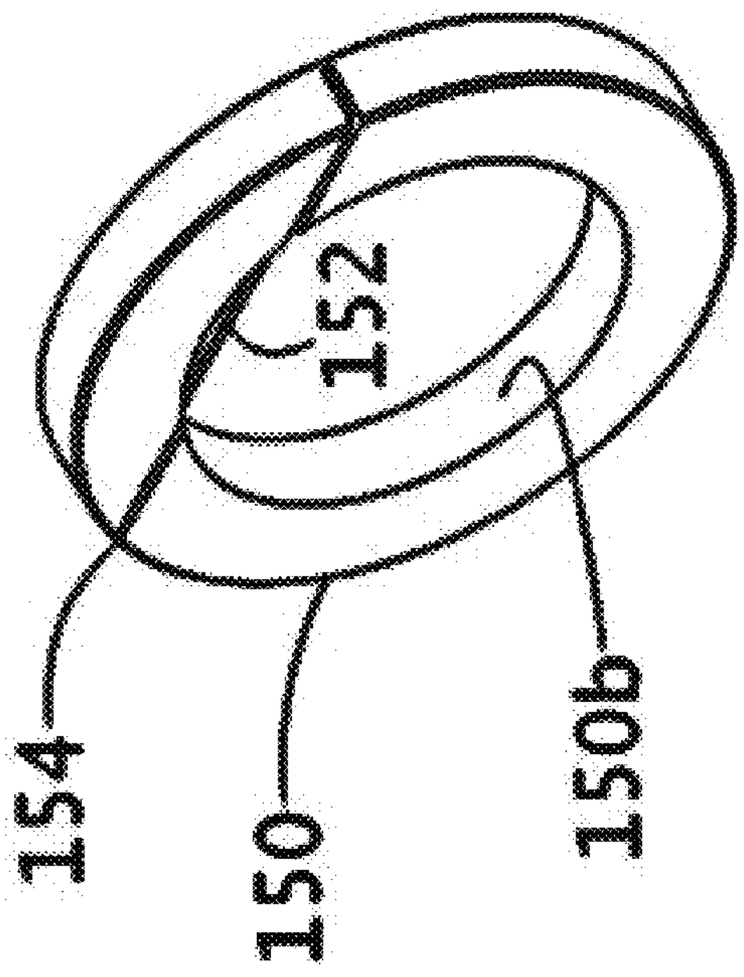

FIG. 11

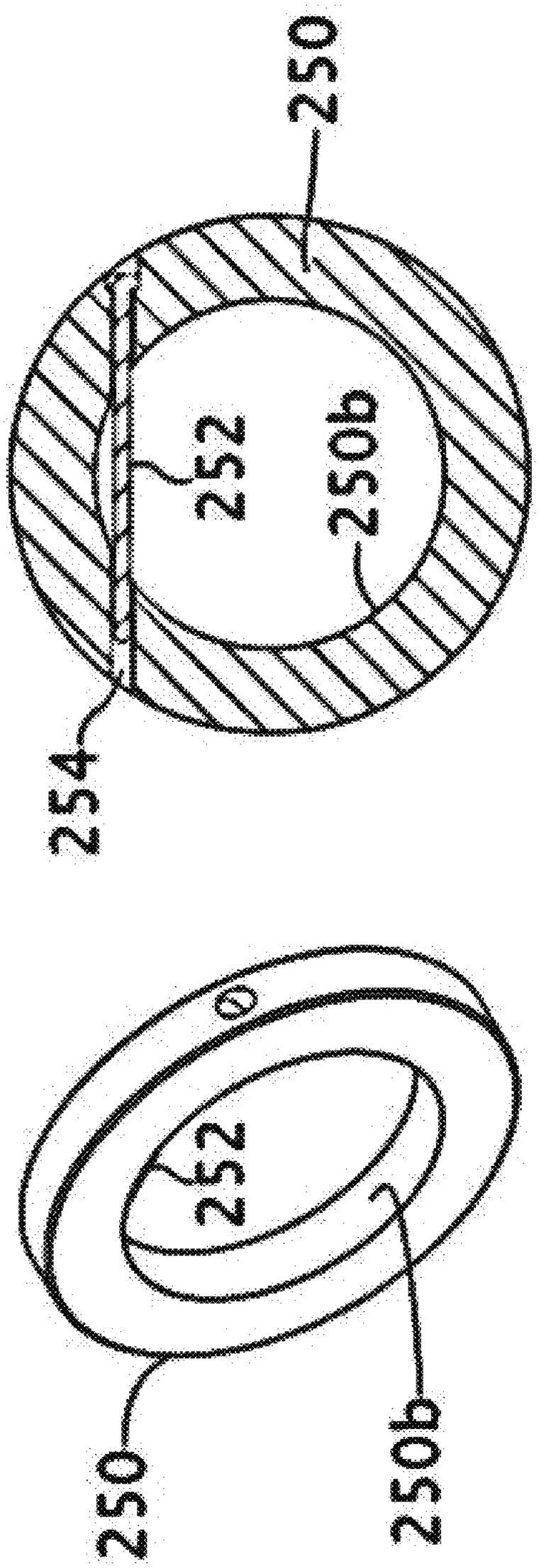

FIG. 14

FIG. 13

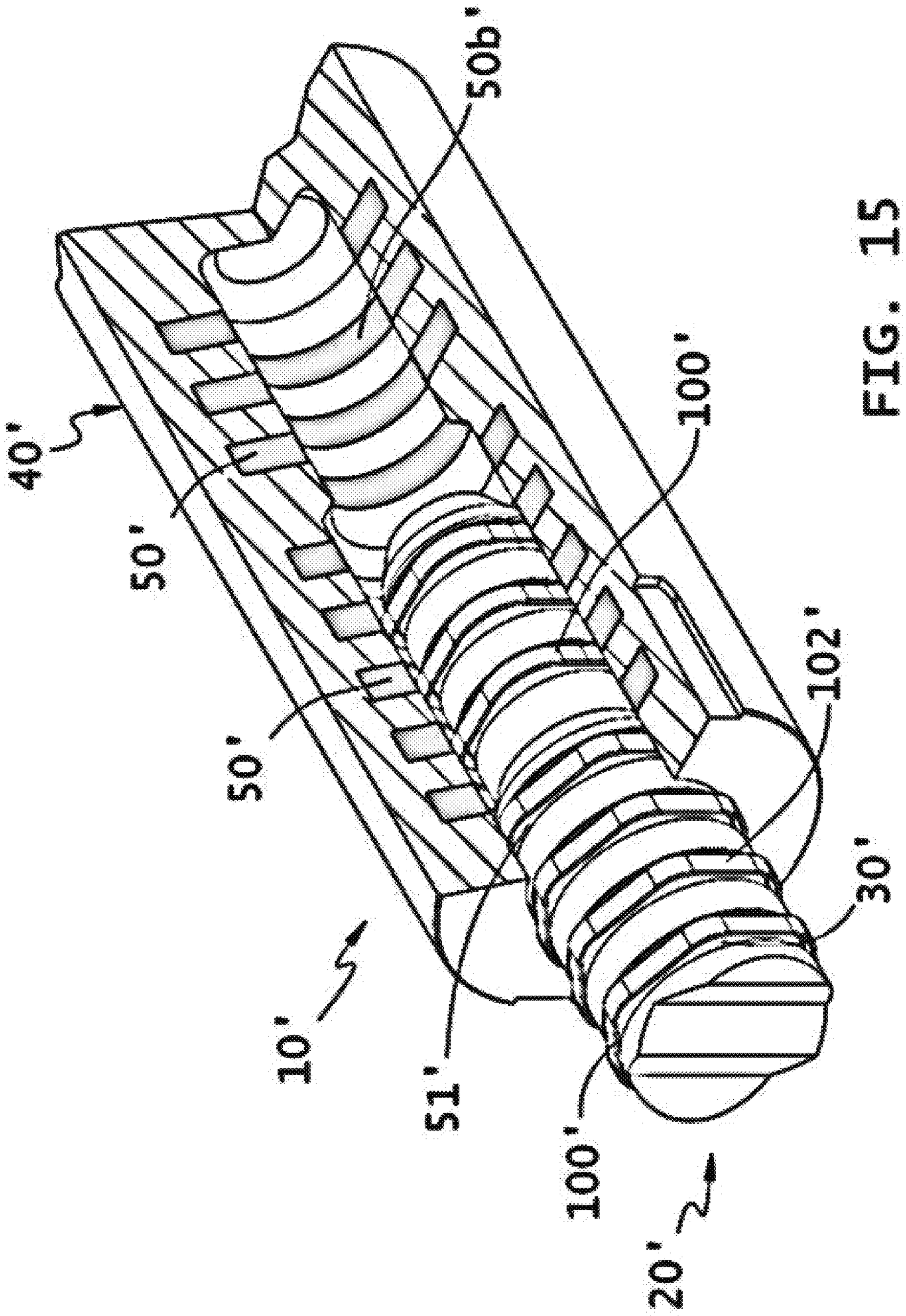

FIG. 15

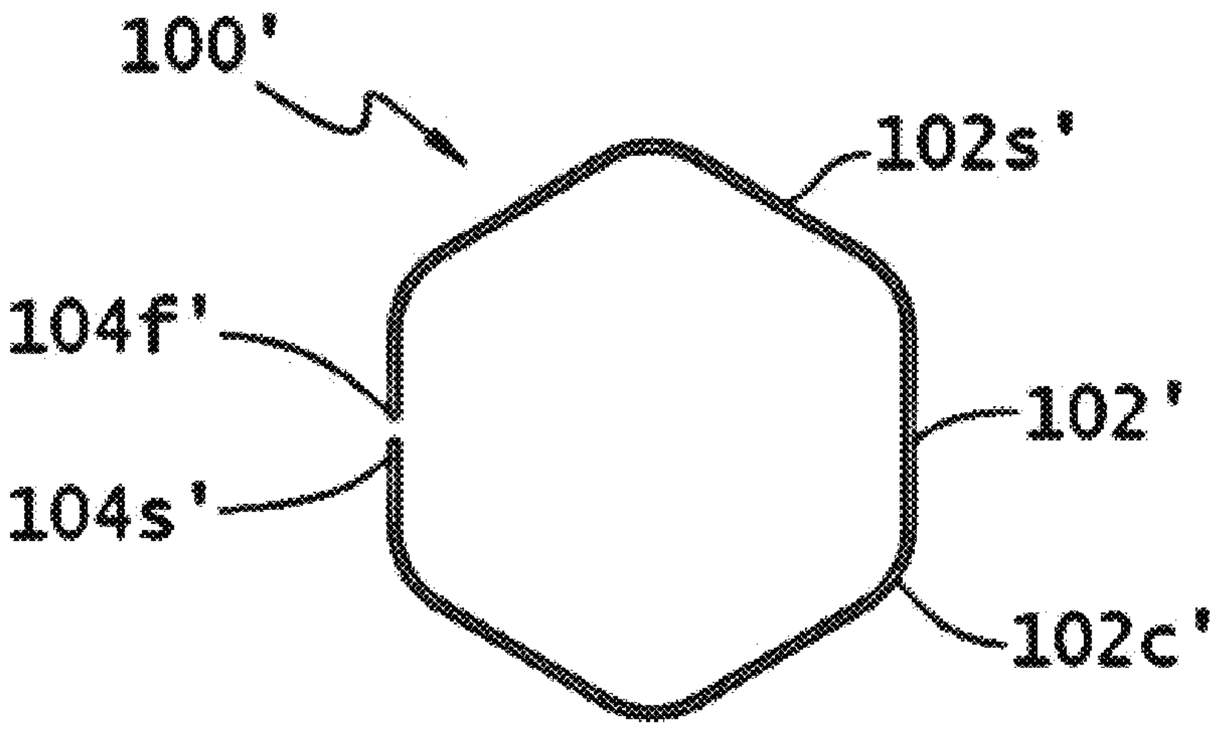

FIG. 16

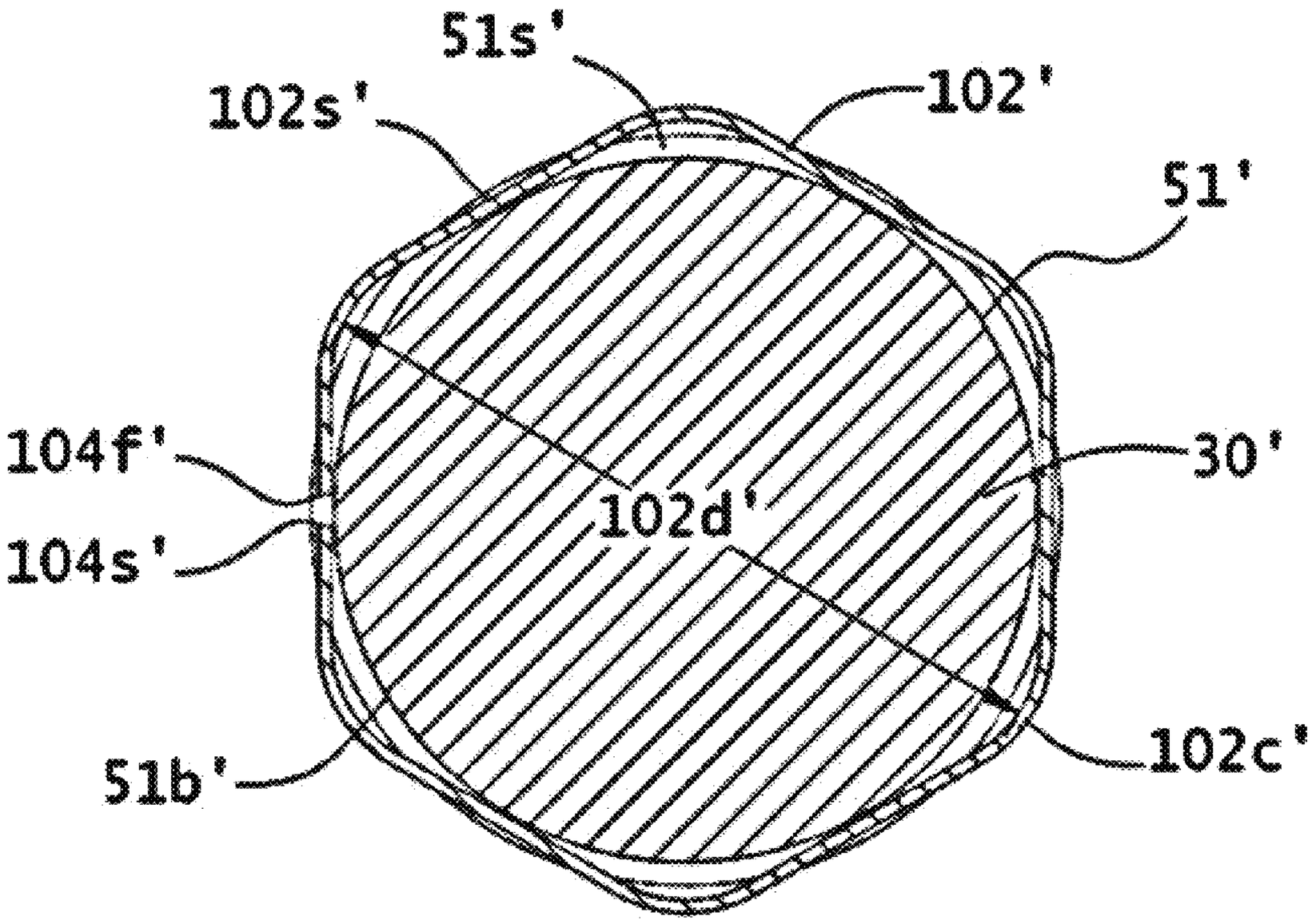

FIG. 17

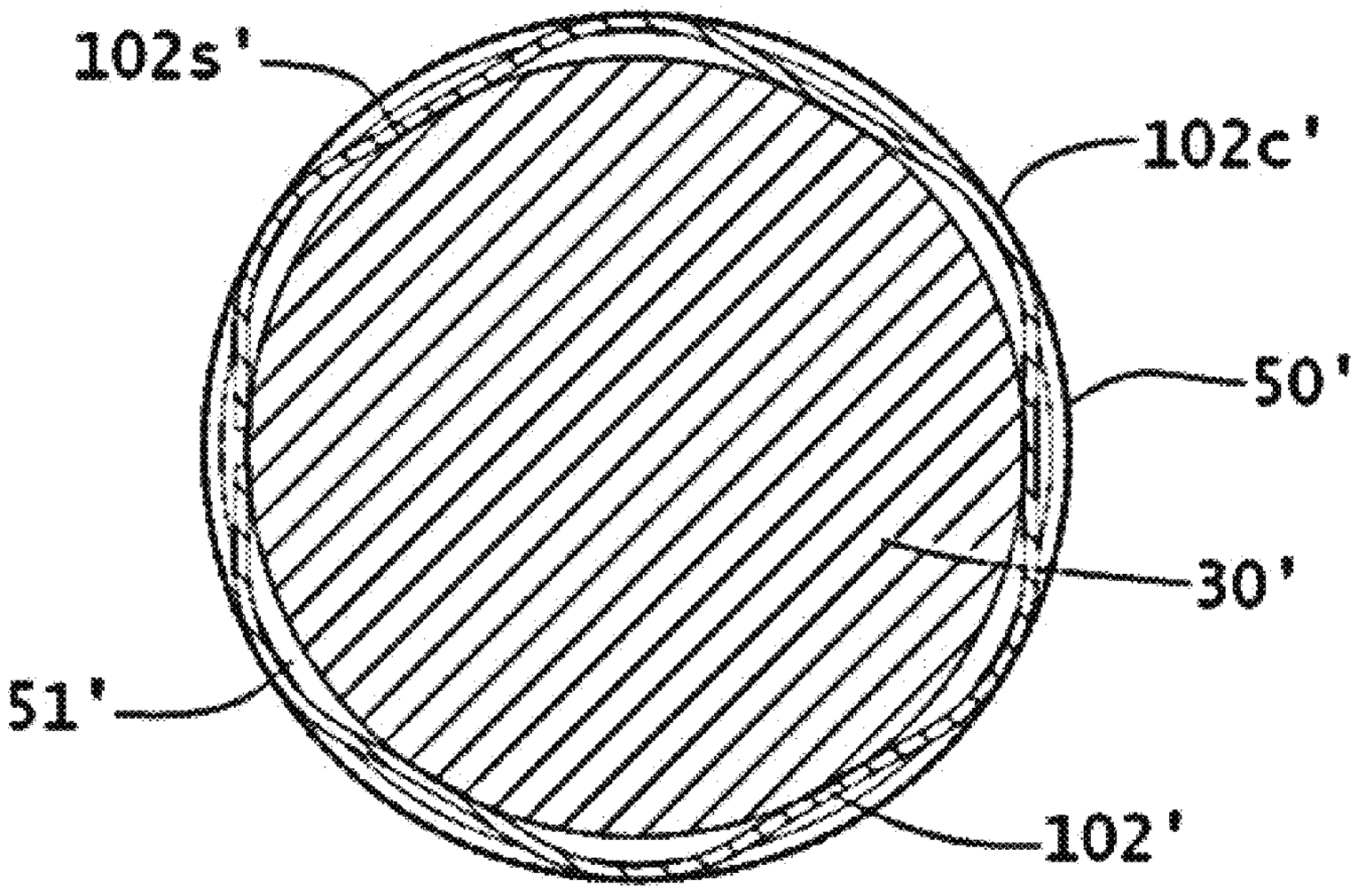

FIG. 18

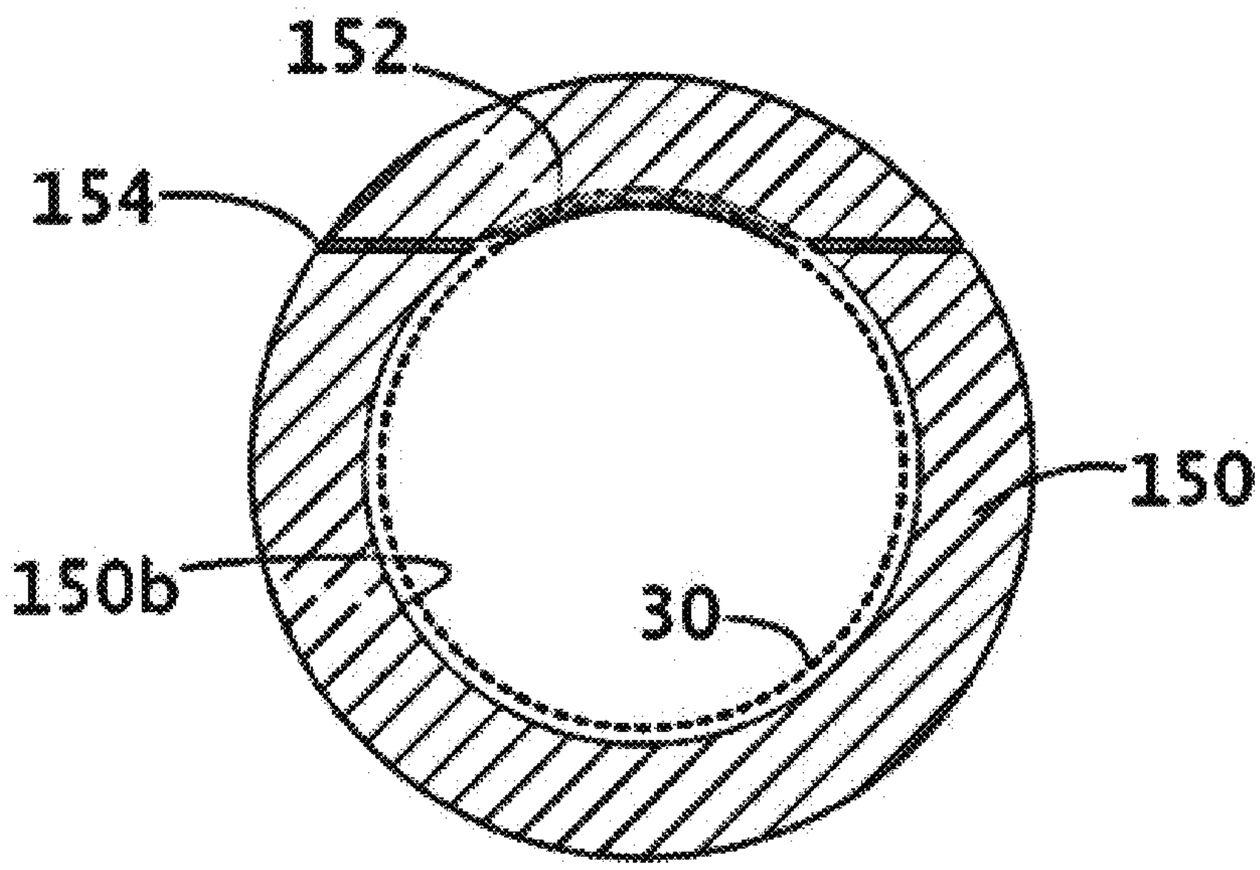

FIG. 19

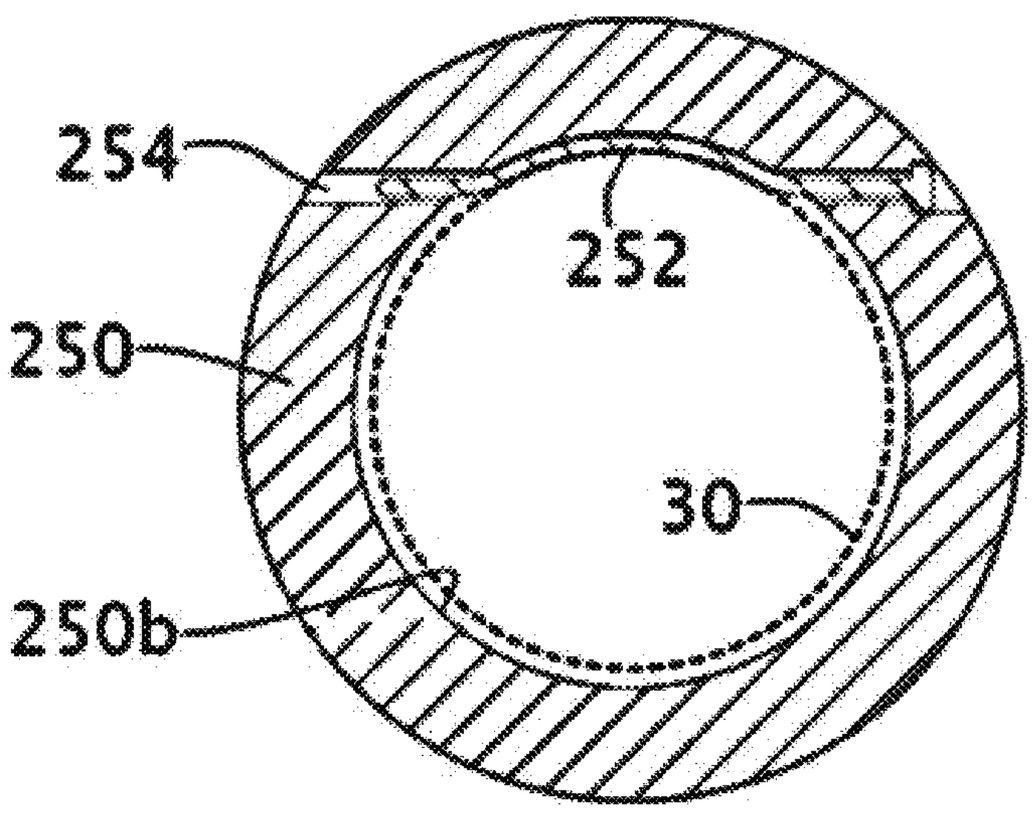

FIG. 20

MULTI-CONDUCTOR ROTARY CONNECTOR

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional Application Ser. No. 62/842,841, filed on May 3, 2019, entitled "Multi-Conductor Rotary Connector." Applicant incorporates by reference herein Application Ser. No. 62/842,841 in its entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to electrical, multiple conductor rotary connectors, and more specifically to the contacts for electrical, multiple conductor rotary connectors.

2. Description of the Related Art

Electrical rotary connectors typically include a male assembly and a female assembly that engage one another and permit rotation of the male and female assemblies with respect to one another. Oftentimes, the joining of the male and female assemblies will have relative rotation as a result of threaded members. Sometimes it is desirable, that upon mating of the male and female assemblies to one another, for relative rotation to exist between the two assemblies while maintaining the electrical contacts.

The male assembly is adapted to removably seat in the female assembly. The male assembly typically has at least two spaced conductor rings on an outer surface and the female assembly has a corresponding number of spaced conductor rings on an inner surface spaced so as to be juxtaposed with the male assembly conductor rings when the male assembly is seated in the female assembly.

Typically, a member often referred to as a contact or electrically-conductive contact is positioned in an annular space between the juxtaposed conductor rings to allow for connector make-up, manufacturing tolerances and to ensure electrical connectivity is maintained between each pair of juxtaposed conductor rings when the male and female assemblies are mated.

One type of contact used by Greene, Tweed & Company of Kulpsville, Pa., is a multi-leaf spring contact. The multi-leaf spring contact is installed within the female assembly. Thin metal leaves are uniformly spaced around the conductor ring in the axial direction with a "free end" of the metal leaf facing the rear of the female assembly. A rubber O-ring is positioned beneath the "free end" to energize the thin leaf springs.

Some shortcomings with the O-ring energized multi-leaf spring contact are: the thin metal leaves are fragile and break easily; the thin metal leaves are easily snagged during cleaning with rags, etc. thus causing breakage and/or permanent damage; low conductor cross-sectional area limiting electrical current capacity; the O-ring energizers are subject to compression set at elevated temperatures; does not allow for unitized plastic molding around contacts due to many leak pathways; and not axially compact.

U.S. Pat. No. 7,052,297 titled "Rotary Connector having Removable and Replaceable Contacts," assigned to Wireline Technologies, Inc. of Houston, Tex., discloses a canted coil spring contact for rotary connectors. The objects of the

invention in the '297 patent are to provide an electrically-conductive contact that is replaceable and that is easily and quickly replaced in the field without extensive disassembly of the rotary connector. Although canted coil springs are easily replaced, they are suspect/prone to having very low durability—especially in harsh operating conditions such as high temperature, high pressure environments, or when subjected to vibrational forces, or cyclical loading—experienced in many applications where rotary connectors are used. The canted coil spring often cracks during operation and is prone to getting snagged and dislodged when cleaning the connector. The canted coil spring may become dislodged during connection or disconnection of the coupler or due to allowable manufacturing tolerances of the connector which may result in slight misalignment of the mating connectors. The canted coil spring is not axially compact as it becomes ovoid when squeezed radially during mating of the rotary connector.

Another prior art rotary electrical connector includes spring-loaded pogo pin contacts. Pogo pins are subject to movement during shock and vibration thus causing potential electrical signal issues and mechanical damage. Pogo pins are prone to shearing during mating of connectors thus causing permanent damage. Other disadvantages with spring-loaded pogo pin contacts are: pogo pins are not replaceable; no unitized plastic molding around contacts is possible due to plastic invasion into back side of the pogo canister; and not radially or axially compact so connectors cannot be as compact.

It is desirable to have a rotary electrical connector that is durable, can withstand intense vibrations and is resistant to fatigue failure. It is further desirable that the connector is durable over numerous connect and disconnect cycles. It is further desirable that the rotary electrical connector is compact. It is further desirable that the rotary electrical connector can work in high temperature, high pressure (HTHP) environments, as for example in the oilfield. It is desirable that the contact has one or more of the following characteristics: high durability, high electrical current capacity, very high shock and vibration tolerance, and little likelihood of damage during maintenance and during connecting and disconnecting the rotary connector.

SUMMARY OF THE INVENTION

The preferred embodiments of the invention provide a rotary connector having a plug and a receptacle with high durability during operation, in addition to having very low likelihood of damage during maintenance. In the rare event that a contact is damaged, the contact is replaceable. The rotary connector has very high shock and vibration tolerance making it well-suited for use in extreme and difficult environments. The preferred embodiments provide a connector having high electrical current capacity. The rotary connector is radially and axially compact, thus allowing for a smaller form factor connector. At least some of the embodiments allow for unitized molded assembly.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

The aspects, features, and advantages of the embodiments of the invention mentioned above are described in more detail by reference to the drawings, wherein like reference numerals represent like elements having the same basic function, in which:

FIG. **1** is cross-sectional view of a rotary connector according to a preferred embodiment of the present invention, showing a plug inserted in a receptacle;

FIG. **2** is a partial perspective view of the rotary connector of FIG. **1**, the perspective view having a portion of the receptacle removed and showing the plug partially within the receptacle;

FIG. **3** is a perspective view of an electrically-conductive contact according to a preferred embodiment of the invention;

FIG. **4** is a front view of the contact shown in FIG. **3**;

FIG. **5** is a cross-sectional view of the contact of FIGS. **3** and **4** received in a groove of a conductor ring in the receptacle, the contact shown in a relaxed position;

FIG. **6** is a cross-sectional view similar to FIG. **5**, showing the contact in a deformed position with the conductor ring of the plug shown in dashed lines;

FIG. **7** is a perspective view of a contact according to another embodiment of the invention;

FIG. **8** is a front view of the contact shown in FIG. **7**;

FIG. **9** is a perspective view of a contact according to another embodiment of the invention;

FIG. **10** is a front view of the contact shown in FIG. **9**;

FIG. **11** is a perspective view of an alternative embodiment of a receptacle conductor ring with a contact inserted into a slot in the conductor ring;

FIG. **12** is a front, cross-sectional view of the conductor ring and contact shown in FIG. **11**;

FIG. **13** is a perspective view of an alternative embodiment of the conductor ring with a contact inserted in a hole in the conductor ring;

FIG. **14** is a front, cross-sectional view of the conductor ring and contact shown in FIG. **13**;

FIG. **15** is a partial perspective view of an alternative embodiment of the rotary connector, the perspective view having a portion of the receptacle removed and showing the plug partially within the receptacle and with electrically-conductive contacts installed on the plug;

FIG. **16** is a front view of an embodiment of an electrically-conductive contact for installation on the plug; and

FIG. **17** is a cross-sectional view of the contact of FIG. **16** received in a groove of a conductor ring in the plug, the contact shown in a relaxed position;

FIG. **18** is a cross-sectional view similar to FIG. **17**, showing the contact in a deformed position with the conductor ring of the receptacle shown in dashed lines;

FIG. **19** is a cross-sectional view similar to FIG. **12**, showing the receptacle conductor ring with the contact in a deformed position and the plug conductor ring shown in dashed lines; and

FIG. **20** is a cross-sectional view similar to FIG. **14**, showing the receptacle conductor ring with the contact in a deformed position and the plug conductor ring shown in dashed lines.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

It should be understood at the outset that although illustrative implementations of one or more embodiments are described below, the disclosed assemblies, systems and methods may be implemented using any number of techniques, whether currently known or not yet in existence. The disclosure should in no way be limited to the illustrative implementations, drawings, and techniques described below, but may be modified within the scope of the appended claims along with their full scope of equivalents.

The following brief definition of terms shall apply throughout the application:

The phrases "in one embodiment," "according to one embodiment," and the like generally mean that the particular feature, structure, or characteristic following the phrase may be included in at least one embodiment of the present invention, and may be included in more than one embodiment of the present invention (importantly, such phrases do not necessarily refer to the same embodiment);

If the specification describes something as "exemplary" or an "example," it should be understood that refers to a non-exclusive example;

The terms "about" or "approximately" or the like, when used with a number, may mean that specific number, or alternatively, a range in proximity to the specific number, as understood by persons of skill in the field of the art;

If the specification states a component or feature "may," "can," "could." "should," "would," "preferably," "possibly," "typically," "optionally," "for example," "often," or "might" (or other such language) be included or have a characteristic, that particular component or feature is not required to be included or to have the characteristic. Such component or feature may be optionally included in some embodiment, or it may be excluded.

Embodiments of the invention will now be described with reference to the figures, in which like numerals reflect like elements throughout. The terminology used in the description presented herein is not intended to be interpreted in any restrictive or limited way, simply because it is being utilized in conjunction with the detailed description of certain specific embodiments of the invention. Furthermore, embodiments of the invention may include several novel features, no single one of which is solely responsible for its desirable attributes or which is essential to practicing the invention described herein.

Referring to FIG. **1**, a rotary connector, generally referred to as **10**, is shown having a plug **20** fully inserted within a receptacle **40**. The rotary connector **10** in FIG. **1** is an eight pin, stepped rotary connector. There are eight electrical conductor rings **30** of the plug **20** that are juxtaposed to and/or in substantially radial alignment with eight electrical conductor rings **50** of the receptacle **40** when the plug **20** is seated in the receptacle **40**. It is to be understood that each pair of opposing conductor rings **30**, **50** acts cooperatively to conduct electricity through the rotary connector **10**.

An electrical wire or conductive member W is routed from each conductor ring **30** within the plug **20** and exits the rear of the plug **20** or connects to a terminal at the rear of the plug **20**. Similarly, an electrical wire or conductive member W is routed from each conductor ring **50** within the receptacle **40** and exits the rear of the receptacle **40** or connects to a terminal at the rear of the receptacle **40**. For purposes of clarity, FIG. **1** shows only one wire W connected to one plug conductor ring **30** and one wire W connected to one receptacle conductor ring **50**. As is well understood in the art, each conductor ring **30** and **50** is connected to a separate wire or conductive member W which is accessible or exits at the rear of the plug **20** and receptacle **40**, respectively.

It is to be understood that the number of pairs of conductor rings **30**, **50** will depend on the number of electrical signals or pathways needed for the specific rotary connector **10**. Thus, while eight pairs of conductor rings are shown in FIG. **1**, this is merely for illustration and not limiting to the invention.

As stated above, the rotary connector **10** shown in FIG. **1** is a stepped rotary connector. The plug **20** has a stepped outer diameter and the receptacle **40** has a stepped inner

diameter. It is to be understood that this is well known to those skilled in the art and often used when there are several pairs of conductor rings **30**, **50** in the rotary connector **10**. It is to be understood that the plug **20** and receptacle **40** of the present invention could both have a uniform diameter or both have a plurality of stepped diameters.

Referring to FIGS. **1** and **2**, the plug **20** includes an insulating body **22** having a head portion **24** and a tail portion **26**. The head portion **24** has a head diameter **24***d* and the tail portion **26** has a tail diameter **26***d*. A tapered transition **28** preferably joins the head portion **24** to the tail portion **26**. The tail diameter **26***d* is larger than the head diameter **24***d*. It is to be understood that the plug insulating body **22** may alternatively be of uniform diameter. The plug insulating body **22** is preferably made of a dielectric or non-electrically conductive material. One such suitable material is polyether ether ketone (PEEK). A forward end **27** of the plug insulating body **22** is preferably tapered or rounded to provide guidance.

With reference to FIG. **1**, the electrical conductor rings **30** of the plug **20** are preferably circular and have a smooth outer surface. FIG. **1** shows three conductor rings **30** on the head portion **24** and five on the tail portion **26**. The number of plug conductor rings **30** will depend on the number of electrical signals or pathways needed for the specific rotary connector **10**. The plug conductor rings **30** are separated from one another by a non-conducting ring, spacer or a portion of the plug insulating body **22** in the event the plug **20** is a molded assembly. The actual assembly of the plug **20** is not critical to the claimed invention. One of ordinary skill in the art is familiar with various ways of assembling the plug **20**.

The plug conductor rings **30** preferably have an outer diameter substantially equal to or slightly greater than the corresponding diameter of the adjacent portion of the plug insulating body **22** in the embodiment shown in FIGS. **1** and **2**. The plug conductor rings **30** on the head portion **24** are designated **30***h* and the plug conductor rings **30** on the tail portion **26** are designated **30***t*. The plug conductor rings **30** are made from an electrically conductive material, as for example, beryllium copper.

The receptacle **40** includes an insulating body **42** that is preferably substantially cylindrical and has a bore **44** open at a front end **46** of the receptacle **40**. The bore **44** is sized and shaped to correspond with the size and shape of the head and tail portions **24** and **26** of the plug **20**. The receptacle **40** includes a number of conductor rings **50** corresponding to the number of plug conductor rings **30**. The receptacle conductor rings **50** that are arranged and designed to align with the plug conductor rings **30***h* on the head portion **24** are designated **50***h* and those arranged and designed to align with the plug conductor rings **30***t* on the tail portion **26** are designated **50***t*. The receptacle conductor rings **50***h* preferably have an axial, circular inner bore **50***b* (FIG. **5**) with an inside diameter slightly greater than the head diameter **24***d* and the outside diameter of the head portion conductor rings **30***h*. Similarly, the receptacle conductor rings **50***t* preferably have an axial, circular inner bore with an inside diameter slightly greater than the tail diameter **26***d* and the outside diameter of the tail portion conductor rings **30***t*. The receptacle conductor rings **50** are made from an electrically conductive material, as for example, beryllium copper.

In a preferred embodiment as shown in FIGS. **1** and **2**, a radially inward-facing groove **51**, preferably annular, is made in the receptacle conductor rings **50** for at least partially receiving an electrically-conductive contact **100**. Preferably, the inward-facing groove **51** is recessed radially outward of the inner bore **50***b* of the receptacle conductor rings **50**. The contacts **100** are shown in the grooves **51** in FIG. **2**. The electrically-conductive contacts **100** are made from an electrically conductive material.

In some embodiments of the present invention, the electrically-conductive contact **100** has a generally annular profile defining an opening. FIGS. **3** and **4** show a preferred design for the electrically-conductive contact **100**. FIGS. **3** and **4** show a generally polygonal-shaped contact **102** having arcuate portions or rounded corners or vertices **102***c* and generally straight segments **102***s*. The generally polygonal-shaped contact **102** shown in FIGS. **3** and **4** includes six substantially straight segments **102***s* joined by rounded corners **102***c* defining an opening within the generally polygonal-shaped contact **102**. Preferably, the generally polygonal-shaped contact **102** is discontinuous and has first and second ends **104***f* and **104***s*, respectively. The contact **102** shown in FIGS. **3** and **4** is the contact **100** shown in the receptacle **40** in FIG. **2**, although other embodiments of the electrically-conductive contact **100** could be used. Preferably, the first and second ends **104***f*, **104***s* are located at a rounded corner **102***c* when the contact **102** is to be installed in the receptacle **40** so that the ends **104***f*, **104***s* are in the groove **51** where they are unlikely to snag on anything.

FIG. **5** shows a cross-sectional view of the six-sided polygonal-shaped contact **102** received within the groove **51** of the receptacle conductor ring **50**. The groove **51** preferably has a pair of sidewalls **51***s* (only one shown) joined by a groove base **51***b* defining a groove width and a groove depth. Preferably, the sidewalls **51***s* extend radially outward from the inner bore **50***b* to the groove base **51***b* and the axial distance between the sidewalls **51***s* defines the groove width. Preferably, the groove width is in the range of about 0.001" to 0.015" wider than the contact width **102***w*. The groove depth is defined by the radial length of the sidewall **51***s*.

The contact **102** in FIG. **5** is in a relaxed position and has a relaxed inscribed diameter **102***d*. The generally straight segments **102***s* in the relaxed position define the relaxed inscribed diameter **102***d*. For the contact **102** shown in FIG. **5**, the relaxed inscribed diameter **102***d* is the shortest distance between oppositely facing generally straight segments **102***s*. At least a portion, typically a mid-portion, of the generally straight segments **102***s* is positioned outside of the groove **51** in the relaxed position as shown in FIG. **5**. Stated another way, the relaxed inscribed diameter **102***d* is smaller than the inside diameter of the receptacle conductor ring **50**. Preferably, the relaxed inscribed diameter **102***d* is smaller than the outer diameter of the corresponding plug conductor ring **30**.

Still referring to FIG. **5**, the contact **102** is in the relaxed position when the plug **20** is uncoupled from the receptacle **40** and when the plug **20** is not juxtaposed or contacting the contact **102**. The first and second ends **104***f* and **104***s* of the generally polygonal-shaped contact **102** are adjacent the groove base **51***b* and preferably have an edge portion contacting the groove base **51***b*. Preferably, each of the rounded corners **102***c* are in contact with the groove base **51***b* when in the relaxed position.

FIG. **6** is representative of when the plug **20** and receptacle **40** are fully joined or coupled together and the contact **102** is in an elastically deformed position. The outer surface of the plug conductor ring **30** is shown in dashed lines in FIG. **6**. Since the outer diameter of the plug conductor ring **30** is preferably at least slightly larger than the relaxed inscribed diameter **102***d* of the contact **102**, the juxtaposed plug conductor ring **30** forces the straight segments **102***s* to bend slightly outwardly such that the contact **102** is slightly

more circular. As shown in FIG. **6**, the elastically deformed straight segments **102***s* provide a substantial amount of surface area contact with the outer surface of the plug conductor ring **30**. Additionally, the contact **102** concurrently retains substantial contact with the groove base **51***b*. It is also to be understood that a portion of the side surfaces of the contact **102** facing the groove sidewalls **51***s* will also likely be in contact with at least one of the sidewalk **51***s*. The contact **102** is sufficiently elastic such that electrical contact is achieved and maintained between the corresponding plug and receptacle conductor rings **30**, **50**, when the plug **20** and receptacle **40** are fully mated, yet when the plug **20** is disconnected or removed from the receptacle **40** the contact **102** remains in the groove **51** and returns to its relaxed position with an inscribed diameter **102***d* smaller than the outer diameter of the mating plug conductor ring **30**.

In the mated condition of the plug **20** and receptacle **40**, the plug conductor rings **30** are radially aligned, or substantially radially aligned, with corresponding receptacle conductor rings **50**.

It is to be understood that the size and shape of the groove **51** is dependent on the type of contact **100** used, in addition to other design factors. Referring to FIGS. **3** and **4**, the contact **102** has a width **102***w* and a thickness **102***t*. The groove width, defined by the distance between the sidewalls **51***s*, is preferably slightly wider than the contact width **102***w*. Following are some representative dimensions for the groove **51** and contact **102** merely for exemplary purposes to illustrate an embodiment. In this example, the contact **102** has a width **102***w* of 0.060" (inches) and a thickness **102***t* of 0.008" and the groove **51** has a width of 0.064" and a depth in the range of 0.016" to 0.027" depending on various factors. Preferably, the dimensions are such that the contact **102** is securely positioned within the groove **51** and remains elastic.

The preferred embodiment of the rotary connector provides the following advantages:

High durability during operation as well as very low likelihood of damage during maintenance;

Contact s replaceable in rare instance of damage;

High electrical current capacity;

Very high shock and vibration tolerance;

Radially and axially compact thus allowing for a smaller form factor connector; and

Allows for unitized molded assembly.

FIGS. **7-14** illustrate other embodiments of electrically-conductive contacts **100**. It is to be understood that the following embodiments of electrically-conductive contacts **100** include all or some of the above advantages.

The contact **100** shown in FIGS. **7** and **8** is another generally polygonal-shaped contact, generally referred to as **112**, having rounded corners or vertices **112***c*. The generally polygonal-shaped contact **112** shown in FIGS. **7** and **8** includes rounded corners **112***c* separated by four generally straight segments **112***s*. Preferably, the generally polygonal-shaped contact **112** is discontinuous and has first and second ends **114***f* and **114***s*, respectively. Preferably, the first and second ends **114***f* and **114***s* are located such that they would remain within an inwardly facing groove **51** and contact the groove base **51***b*.

FIGS. **9** and **10** show a generally marcel-shaped contact **122** having a plurality of rounded external corners or vertices **122***c*. The generally marcel-shaped contact **122** includes a plurality of rounded external corners **122***c* separated by generally wavy segments **122***s*. Preferably, the generally marcel-shaped contact **122** is discontinuous and has first and second ends **124***f* and **124***s*, respectively. Preferably, the first and second ends **124***f* and **124***s* are located such that they would remain within an inwardly-facing groove **51** and contact the groove base **51***b*.

FIGS. **11** and **12** show an alternative receptacle conductor ring **150** having an axial inner bore **150***b*. The axial inner bore **150***b* may be a continuous axial bore, without the need to have an inwardly-facing groove. A slot **154** extends transversely through the conductor ring **150** and intersects the inner bore **150***b* at two locations. An electrically-conductive contact **152** in the form of a flexible beam is inserted into e slot and within a portion of the inner bore **150***b* as shown in FIG. **12**. The contact **152** has a relaxed position in which the contact **152** is a substantially straight member passing within the inner bore **150***b* of the receptacle conductor ring **150** as shown in FIGS. **11** and **12**.

FIG. **19** is representative of when the plug **20** and receptacle **40** are fully joined or coupled together and the contact **152** is in an elastically deformed position. The outer surface of the plug conductor ring **30** is shown in dashed lines. The outer diameter of the plug conductor ring **30** is sized so that upon mating of the plug with the receptacle, the mating plug conductor ring **30** contacts and elastically deforms the contact **152** within the inner bore **150***b*. The contact **152** is sufficiently elastic that electrical contact is achieved when deformed by plug connector ring **30**, yet when disconnected from the plug the contact **152** returns to its relaxed straight condition. The contact **152** may have a polygonal or rounded cross-section. In this alternative, the contact **152** is replaceable if the receptacle **40** is assembled, for example, by stacking insulator rings and conductor rings.

FIGS. **13** and **14** show another alternative receptacle conductor ring **250** similar to the one shown in FIGS. **11** and **12**. FIGS. **13** and **14** show an alternative receptacle conductor ring **250** having an axial inner bore **250***b*. The axial inner bore **250***b* may be a continuous axial bore, without the need to have an inwardly-facing groove. A transverse bore **254** extends through the conductor ring **250** and intersects the axial inner bore **250***b* at two locations. An electrically-conductive contact **252** is inserted into the transverse bore **254** in the conductor ring **250** and within a portion of the axial inner bore **250***b* as shown in FIG. **14**. The contact **252** has a relaxed position in which the contact **252** is a substantially straight member passing within the axial inner bore **250***b* of the receptacle conductor ring **250** as shown in FIG. **14**.

FIG. **20** is representative of when the plug **20** and receptacle **40** are fully joined or coupled together and the contact **252** is in an elastically deformed position. The outer surface of the plug conductor ring **30** is shown in dashed lines. The outer diameter of the plug conductor ring **30** is sized so that upon mating of the plug **20** with the receptacle **40**, the mating plug conductor ring **30** contacts and elastically deforms the contact **252** within the inner bore **250***b*. The contact **252** is sufficiently elastic that electrical contact is achieved when deformed by plug connector ring **30**, yet when disconnected from the plug the contact **252** returns to its relaxed straight condition. Preferably, the contact **252** has a circular cross-section. If the contact **252** is press-fitted in the conductor ring **250**, this embodiment may be used in a molded assembly. If the contact **252** is not press-fitted and the receptacle can be disassembled, the contact **252** may be replaceable.

FIG. **15** shows an alternative embodiment of the rotary connector, generally designated **10'**, which is similar in many respects with the rotary connector **10** shown in FIGS. **1** and **2**. The primary difference is that the rotary connector **10'** has the electrically-conductive contacts **100'** installed on

the plug conductor rings **30'**, preferably in outwardly-facing grooves **51'** and the receptacle conductor rings **50'** have a smooth inner bore **50***b*'. The contact **102'** shown is similar in shape to the contact **102** of FIGS. **3** and **4**. The contact **102'** is discontinuous and preferably has first and second ends **104***f*' and **104***s*' at a mid-portion of a generally straight segment **102***s*' as shown in FIG. **16**.

FIG. **17** shows a cross-sectional view of the six-sided polygonal-shaped contact **102'** received within the groove **51'** of the plug conductor ring **30'**. The groove **51'** preferably has a pair of sidewalls **51***s*' (only one shown) joined by a groove base **51***b*' defining a groove width and a groove depth. The contact **102'** is in a relaxed position and has a relaxed inscribed diameter **102***d*'. The rounded corners **102***c*' in the relaxed position define the relaxed inscribed diameter **102***d*'. For the contact **102'** shown in FIG. **17**, the relaxed inscribed diameter **102***d*' is the longest distance between oppositely facing rounded corners **102***c*'. At least a portion, typically a mid-portion, of the rounded corners **102***c*' is positioned outside of the groove **51'** in the relaxed position as shown in FIG. **17**. Preferably, the relaxed inscribed diameter **102***d*' is larger than the inside diameter of the receptacle conductor ring **50'**. Preferably, the relaxed inscribed diameter **102***d*' is larger than the outside diameter of the corresponding plug conductor ring **30'**.

Still referring to FIG. **17**, the contact **102'** is in the relaxed position when the plug **20'** is uncoupled from the receptacle **40'** and when the receptacle **40'** is not juxtaposed or contacting the contact **102'**. The first and second ends **104***f*' and **104***s*' of the generally polygonal-shaped contact **102'** are preferably adjacent the groove base **51***b*' and preferably have an edge portion contacting the groove base **51***b*'. Preferably, a portion of each of the generally straight segments **102***s*' is in contact with the groove base **51***b*' when in the relaxed position.

FIG. **18** is representative of when the plug **20'** and receptacle **40'** are fully joined or coupled together and the contact **102'** is in an elastically deformed position. The inner surface of the receptacle conductor ring **50'** is shown in dashed lines, Since the inner diameter of the receptacle conductor ring **50'** is preferably at least slightly smaller than the relaxed inscribed diameter **102***d*' of the contact **102'**, the juxtaposed receptacle conductor ring **50'** forces the contact **102'** to become slightly more circular. As shown in FIG. **18**, the elastically deformed contact **102'** provides a substantial amount of surface area contact with the inner surface of the receptacle conductor ring **50'** while concurrently retaining substantial contact with the groove base **51***b*'. It is also to be understood that a portion of the side surfaces of the contact **102'** facing the groove sidewalls **51***s*' will also likely be in contact with at least one of the sidewalls **51***s*'. The contact **102'** is sufficiently elastic such that electrical contact is achieved and maintained between the corresponding plug and receptacle conductor rings **30'**, **50'**, when the plug **20'** and receptacle **40'** are fully mated, yet when the plug **20'** is disconnected or removed from the receptacle **40'** the contact **102'** remains in the groove **51'** and returns to its relaxed position with an inscribed diameter **102***d*' larger than the inner diameter of the mating receptacle conductor ring **50'**.

It is to be understood at the groove in the conductor ring in the above described embodiments will vary based on the size, shape and type of contact. The groove is designed to create the required force for each size of contact.

It is to be understood that the cross-section shapes of the contacts in the figures are not limited to the shape illustrated (i.e., rectangular) but may comprise other shapes including, but not limited to, round.

It is to be understood that insulators between adjacent contacts can be discrete pieces or a unitized molded system. Additionally, the system allows for optional hermetic sealing of electrical connector within mating housings.

An analysis of the force required for the contact **102** shown in FIGS. **3** and **4** to yield in bending where the width **102***w* is 0.06", thickness **102***t* is 0.008" and length is 0.17" results in a force of 1.58 Newtons or 0.355 lbs. Comparable analysis for the multi-leaf spring and the canted coil spring designs described in the Background of the Invention result in yielding with forces significantly lower than for the preferred embodiment as shown below:

Design	Force (Newtons)	Force (Pounds)
FIGS. 3-4 Embodiment	1.58	0.355
Multi-Leaf Spring	0.075	0.017
Canted Coil Spring	0.175	0.039

The foregoing disclosure and description of the invention are illustrative and explanatory thereof, and various changes in the size, shape and materials, as well as in the details of the illustrated construction, may be made without departing from the spirit of the invention. The present embodiment is, therefore, to be considered as merely illustrative and not restrictive, the scope of the invention being indicated by the claims rather than the foregoing description, and all changes which come within the meaning and range of equivalence of the claims are therefore intended to be embraced therein.

While the invention has been described in detail above with reference to specific embodiments, it will be understood that modifications and alterations in the embodiments disclosed may be made by those practiced in the art without departing from the spirit and scope of the invention. All such modifications and alterations are intended to be covered. In addition, all publications cited herein are indicative of the level of skill in the art and are hereby incorporated by reference in their entirety as if each had been individually incorporated by reference and fully set forth.

We claim:

1. An electrical connector (**10**) comprising a plug (**20**) arranged and designed to connect to a receptacle (**40**);

a) the plug (**20**) comprising:
  i) an electrically-insulating plug body (**22**);
  ii) a plug conductor ring (**30**) having an outer diameter; and
  iii) a plug electrically-conductive member (W) connected to the plug conductor ring (**30**), the plug electrically-conductive member (W) within the plug body (**22**) and exiting an end of the plug body (**22**); and

b) the receptacle (**40**) comprising:
  i) an electrically-insulating receptacle body (**42**);
  ii) a receptacle conductor ring (**50**) having an axial inner bore (**50***b*);
  iii) a receptacle electrically-conductive member (W) connected to the receptacle conductor ring (**50**) and exiting an end of the receptacle body (**42**);
  iv) an electrically-conductive contact (**100**) contacting the receptacle conductor ring (**50**), the electrically-conductive contact (**100**) having a generally annular, polygonal-shaped axial profile comprising a plurality of substantially straight segments (**102***s*) joined by a plurality of rounded corners (**102***c*) defining an axial

opening, the electrically-conductive contact (**100**) having a relaxed position and an elastically deformed position,

in the relaxed position, the electrically-conductive contact (**100**) has a relaxed inscribed diameter (**102***d*) that is smaller than the outer diameter of the plug conductor ring (**30**),

in the elastically-deformed position, the electrically-conductive contact (**100**) is elastically deformed within the axial inner bore (**50***b*) by the plug conductor ring (**30**), the plug conductor ring (**30**) contacting the electrically-conductive contact (**100**) and electrical contact is achieved between the plug conductor ring (**30**) and the receptacle conductor ring (**50**), and

upon removal of the plug conductor ring (**30**) from contact with the electrically-conductive contact (**100**), the electrically-conductive contact (**100**) returns to the relaxed position.

2. The electrical connector (**10**) of claim **1**, wherein the plug conductor ring (**30**) is one of a plurality of plug conductor rings (**30**), the receptacle conductor ring (**50**) is one of a plurality of receptacle conductor rings (**50**), and the electrically-conductive contact (**100**) is one of a plurality of electrically-conductive contacts (**100**), wherein the number of plug conductor rings (**30**), the number of receptacle conductor rings (**50**) and the number of electrically-conductive contacts (**100**) is the same.

3. The electrical connector (**10**) of claim **1**, wherein upon insertion of the plug (**20**) into the receptacle (**40**) and substantially radially aligning the plug and receptacle conductor rings (**30** and **50**), the plurality of substantially straight segments (**102***s*) elastically deform and provide electrical contact with the plug conductor ring (**30**) and the plurality of rounded corners (**102***c*) provide electrical contact with the receptacle conductor ring (**50**).

4. The electrical connector (**10**) of claim **1**, wherein the receptacle conductor ring (**50**) has an annular groove (**51**) facing radially inward, and at least a portion of the electrically-conductive contact (**100**) is in the annular groove (**51**).

5. The electrical connector (**10**) of claim **4**, wherein at least a portion of the electrically-conductive contact (**100**) is not in the annular groove (**51**).

6. The electrical connector (**10**) of claim **4**, wherein at least a portion of the plurality of substantially straight segments (**102***s*) is not in the annular groove (**51**).

7. The electrical connector (**10**) of claim **4**, wherein at least a portion of each of the plurality of substantially straight segments (**102***s*) is not in the annular groove (**51**).

8. The electrical connector (**10**) of claim **4**, wherein at least a portion of the plurality of rounded corners (**102***c*) is in the annular groove (**51**).

9. The electrical connector (**10**) of claim **4**, wherein at least a portion of each of the plurality of rounded corners (**102***c*) is in the annular groove (**51**).

10. The electrical connector (**10**) of claim **4**, wherein the annular groove (**51**) comprises a pair of sidewalls (**51***s*) extending radially outward from the inner bore (**50***b*) to a groove base (**51***b*), and at least a portion of each of the plurality of rounded corners (**102***c*) contacts the groove base (**51***b*).

11. The electrical connector (**10**) of claim **4**, wherein the annular groove (**51**) comprises a pair of sidewalls (**51***s*) extending radially outward from the inner bore (**50***b*) to a groove base (**51***b*), and an axial distance between the pair of sidewalls (**51***s*) defines a groove width, and the electrically-conductive contact (**100**) has a contact width (**102***w*),

wherein the groove width is in the range of about 0.001" to 0.015" wider than the contact width (**102***w*).

12. The electrical connector (**10**) of claim **4**, wherein the electrically-conductive contact (**100**) is discontinuous and has first and second ends (**104***f*, **104***s*) received in the annular groove (**51**).

13. The electrical connector (**10**) of claim **12**, wherein no portion of the first and second ends (**104***f*, **104***s*) is in the axial inner bore (**50***b*) of the receptacle conductor ring (**50**).

14. The electrical connector (**10**) of claim **4**, wherein the annular groove (**51**) comprises a pair of sidewalls (**51***s*) extending radially outward from the inner bore (**50***b*) to a groove base (**51***b*), and at least a portion of the plurality of rounded corners (**102***c*) contact the groove base (**51***b*).

15. The electrical connector (**10**) of claim **14**, wherein a groove depth is defined by a radial length of one of the sidewalls (**51***s*), and the plurality of substantially straight segments (**102***s*) and the plurality of rounded corners (**102***c*) have a contact thickness (**102***t*) that is less than the groove depth.

16. An electrical connector (**10**) comprising a plug (**20**) arranged and designed to connect to a receptacle (**40**);

a) the plug (**20**) comprising:

i) an electrically-insulating plug body (**22**);

ii) a plug conductor ring (**30**); and

iii) a plug electrically-conductive member (W) connected to the plug conductor ring (**30**), the plug electrically-conductive member (W) within the plug body (**22**) and exiting an end of the plug body (**22**); and

b) the receptacle (**40**) comprising:

i) an electrically-insulating receptacle body (**42**);

ii) a receptacle conductor ring (**50**) having an axial inner bore (**50***b*) and an annular groove (**51**) facing radially inward, the annular groove (**51**) having an axial groove width;

iii) a receptacle electrically-conductive member (W) connected to the receptacle conductor ring (**50**) and exiting an end of the receptacle body (**42**); and

iv) an electrically-conductive contact (**100**) being discontinuous annularly defining first and second ends and having a generally annular profile defining an axial opening, the electrically-conductive contact (**100**) having a contact width (**102***w*) in an axial direction being less than the axial groove width, at least a portion of the electrically-conductive contact (**100**) received in and contacting the annular groove (**51**) and at least a portion of the electrically-conductive contact (**100**) not received in the annular groove (**51**),

wherein upon insertion of the plug (**20**) into the receptacle (**40**) and substantially radially aligning the plug and receptacle conductor rings (**30** and **50**), the electrically-conductive contact (**100**) is elastically deformed and provides electrical contact between the plug conductor ring (**30**) and the receptacle conductor ring (**50**).

17. The electrical connector (**10**) of claim **16**, wherein the annular groove (**51**) comprises a pair of sidewalls (**51***s*) extending radially outward from the inner bore (**50***b*) to a groove base (**51***b*), and an axial distance between the pair of sidewalls (**51***s*) defines the axial groove width, and the electrically-conductive contact (**100**) has a contact width (**102***w*),

wherein the axial groove width is in the range of 0.001" to 0.015" wider than the contact width (**102***w*).

18. The electrical connector (**10**) of claim **16**, wherein the electrically-conductive contact (**100**) comprises a plurality of substantially straight segments (**102***s*) joined by a plurality of corners (**102***c*), and the generally annular profile and the defined axial opening are generally polygonal-shaped.

19. The electrical connector (**10**) of claim **18**, wherein at least a portion of the plurality of substantially straight segments (**102***s*) is not in the groove (**51**).

20. The electrical connector (**10**) of claim **18**, wherein upon insertion of the plug (**20**) into the receptacle (**40**) and substantially radially aligning the plug and receptacle conductor rings (**30** and **50**), the plurality of substantially straight segments (**102***s*) elastically deform and provide electrical contact with the plug conductor ring (**30**) and the plurality of corners (**102***c*) provide electrical contact with the receptacle conductor ring (**50**).

21. The electrical connector (**10**) of claim **18**, wherein the annular groove (**51**) comprises a pair of sidewalls (**51***s*) extending radially outward from the axial inner bore (**50***b*) to a groove base (**51***b*),

wherein the axial groove width is defined by an axial distance between the pair of sidewalls (**51***s*) and a groove depth is defined by a radial length of one of the sidewalls (**51***s*), and

the plurality of substantially straight segments (**102***s*) and the plurality of corners (**102***c*) have a contact thickness (**102***t*) that is less than the groove depth.

22. The electrical connector (**10**) of claim **16**, wherein the first and second ends (**104***f*, **104***s*) are received in the groove (**51**) and no portion of the first and second ends (**104***f*, **104***s*) is in the axial inner bore (**50***b*) of the receptacle conductor ring (**50**).

23. The electrical connector (**10**) of claim **22**, wherein the electrically-conductive contact (**100**) comprises a plurality of wavy segments (**102***s*) joined by a plurality of rounded external corners (**102***c*).

24. An electrical connector (**10**) comprising a plug (**20**) arranged and designed to connect to a receptacle (**40**);

a) the plug (**20**) comprising:

i) an electrically-insulating plug body (**22**);

ii) a plug conductor ring (**30**) having an outer diameter; and

iii) a plug electrically-conductive member (W) connected to the plug conductor ring (**30**), the plug electrically-conductive member (W) within the plug body (**22**) and exiting an end of the plug body (**22**); and

b) the receptacle (**40**) comprising:

i) an electrically-insulating receptacle body (**42**);

ii) a receptacle conductor ring (**50**) having an axial inner bore (**50***b*) and an annular groove (**51**) facing radially inward;

iii) a receptacle electrically-conductive member (W) connected to the receptacle conductor ring (**50**) and exiting an end of the receptacle body (**42**);

iv) an electrically-conductive contact (**100**) contacting the receptacle conductor ring (**50**), at least a portion of the electrically-conductive contact (**100**) is in the annular groove (**51**), the electrically-conductive contact (**100**) having a generally annular, polygonal-shaped profile and comprising a plurality of substantially straight segments (**102***s*) joined by a plurality of rounded corners (**102***c*) defining an axial opening, the electrically-conductive contact (**100**) being discontinuous and having first and second ends (**104***f*, **104***s*) received in the annular groove (**51**), the electrically-conductive contact (**100**) having a relaxed position and an elastically deformed position,

in the relaxed position, the electrically-conductive contact (**100**) has a relaxed inscribed diameter (**102***d*) that is smaller than the outer diameter of the plug conductor ring (**30**),

in the elastically-deformed position, the electrically-conductive contact (**100**) is elastically deformed within the axial inner bore (**50***b*) by the plug conductor ring (**30**), the plug conductor ring (**30**) contacting the electrically-conductive contact (**100**) and electrical contact is achieved between the plug conductor ring (**30**) and the receptacle conductor ring (**50**), and

upon removal of the plug conductor ring (**30**) from contact with the electrically-conductive contact (**100**), the electrically-conductive contact (**100**) returns to the relaxed position.

25. The electrical connector (**10**) of claim **24**, wherein no portion of the first and second ends (**104***f*, **104***s*) is in the axial inner bore (**50***b*) of the receptacle conductor ring (**50**).

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(54) **MULTI-CONDUCTOR ROTARY CONNECTOR**

(71) Applicant: **RAMPART PRODUCTS LLC**, Houston, TX (US)

(72) Inventors: **Sean W. Carter**, Houston, TX (US); **Michael A. Czuppon**, Houston, TX (US); **Edward J. Beshoory**, Houston, TX (US)

(73) Assignee: **RAMPART PRODUCTS LLC**, Houston, TX (US)

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CPC ***H01R 13/187*** (2013.01); ***H01R 13/10*** (2013.01); ***H01R 13/111*** (2013.01); ***H01R 13/17*** (2013.01); ***H01R 24/58*** (2013.01); ***H01R 39/64*** (2013.01)

(58) **Field of Classification Search**
CPC H01R 13/187; H01R 13/10; H01R 13/111; H01R 13/17; H01R 24/58; H01R 39/64; H01R 13/5202; H01R 39/00; H01R 24/38
See application file for complete search history.

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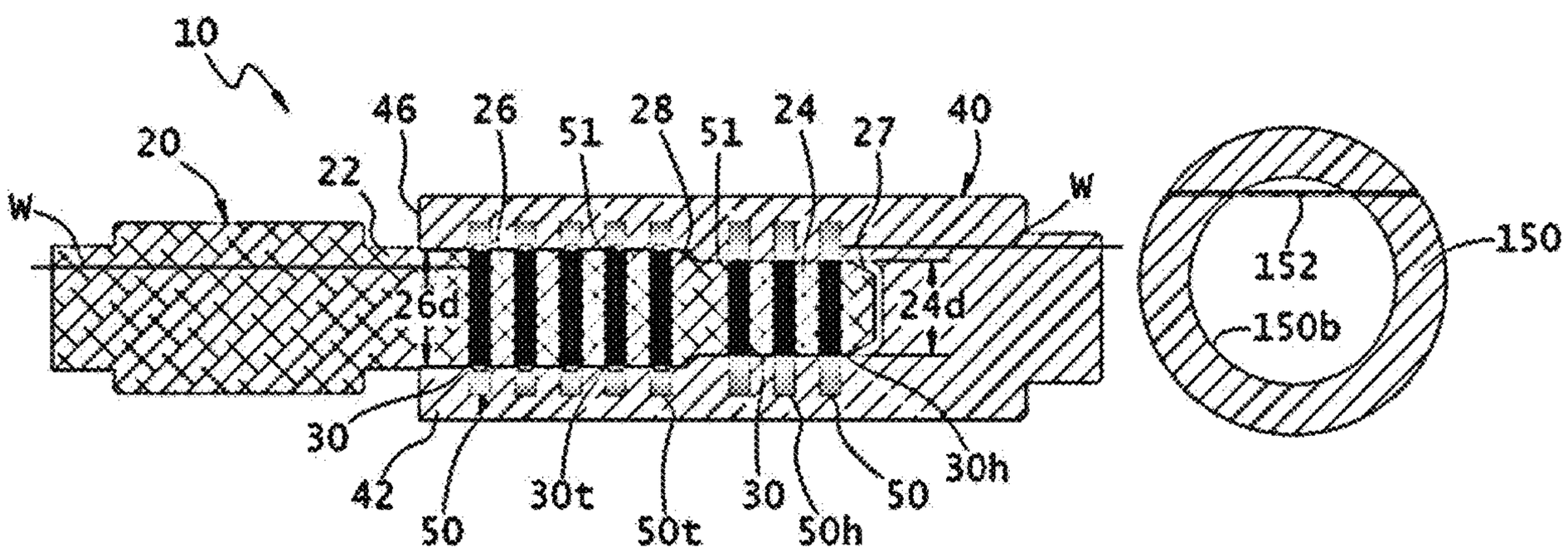
Primary Examiner — Travis S Chambers
(74) *Attorney, Agent, or Firm* — Bracewell LLP; Douglas W. Rommelmann

(57) **ABSTRACT**

An electrical connector comprising a plug arranged and designed to connect to a receptacle. The plug includes an electrically-insulating body, a conductor ring, and a conductive member connected to the plug conductor ring. The receptacle includes an electrically-insulating body, a conductor ring having an axial inner bore and an annular groove facing radially inward, a conductive member connected to the receptacle conductor ring, and an electrically-conductive contact having a generally annular profile, at least a portion of the electrically-conductive contact received in and contacting the annular groove and at least a portion of the electrically-conductive contact not received in the annular groove. Upon insertion of the plug into the receptacle and substantially radially aligning the plug and receptacle conductor rings, the electrically-conductive contact is elastically deformed and provides electrical contact between the plug conductor ring and the receptacle conductor ring.

13 Claims, 14 Drawing Sheets



Related U.S. Application Data

(60) Provisional application No. 62/842,841, filed on May 3, 2019.

(51) **Int. Cl.**

H01R 13/10	(2006.01)
H01R 13/17	(2006.01)
H01R 13/11	(2006.01)
H01R 24/58	(2011.01)

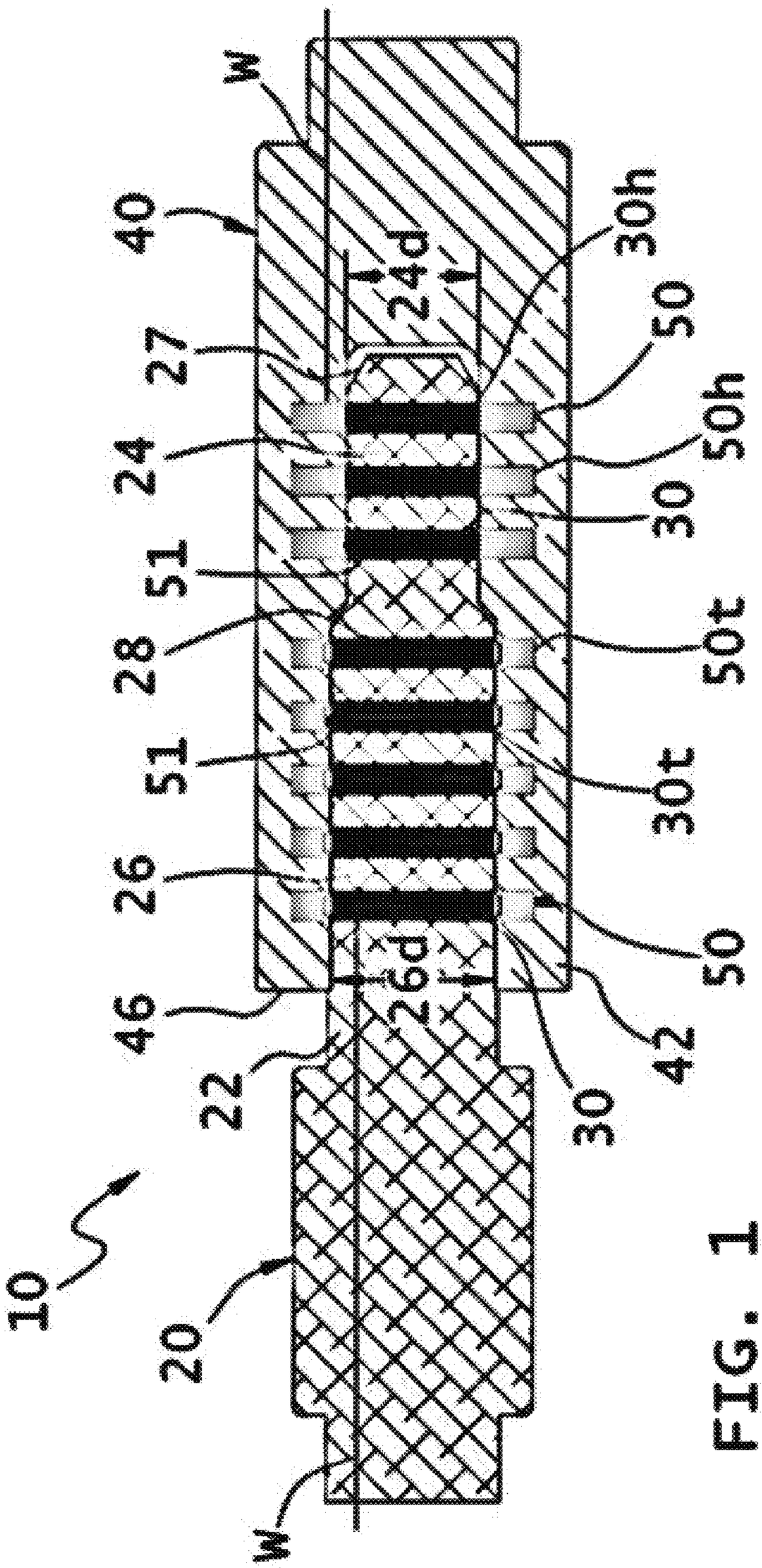

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FIG. 1

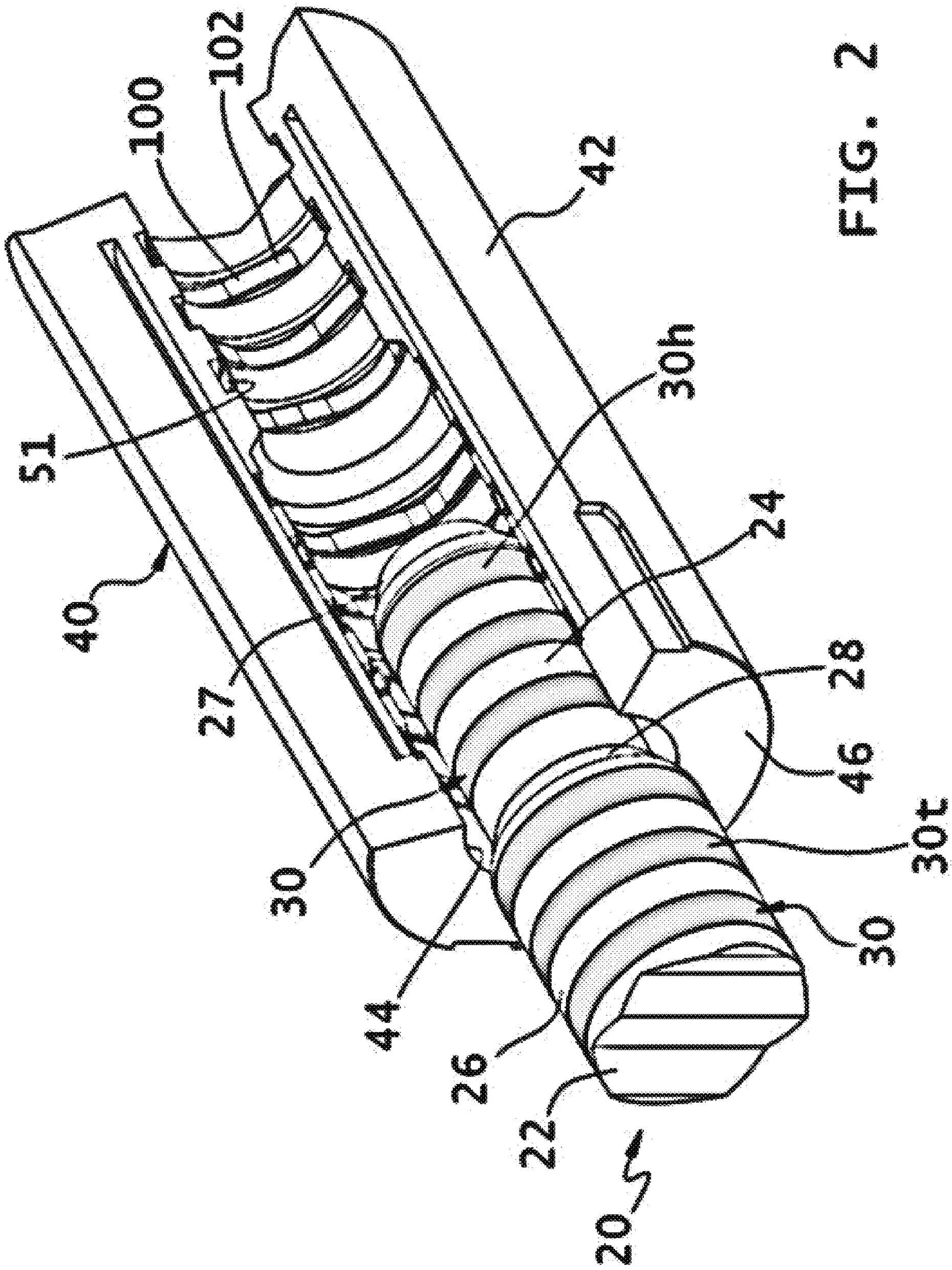

FIG. 2

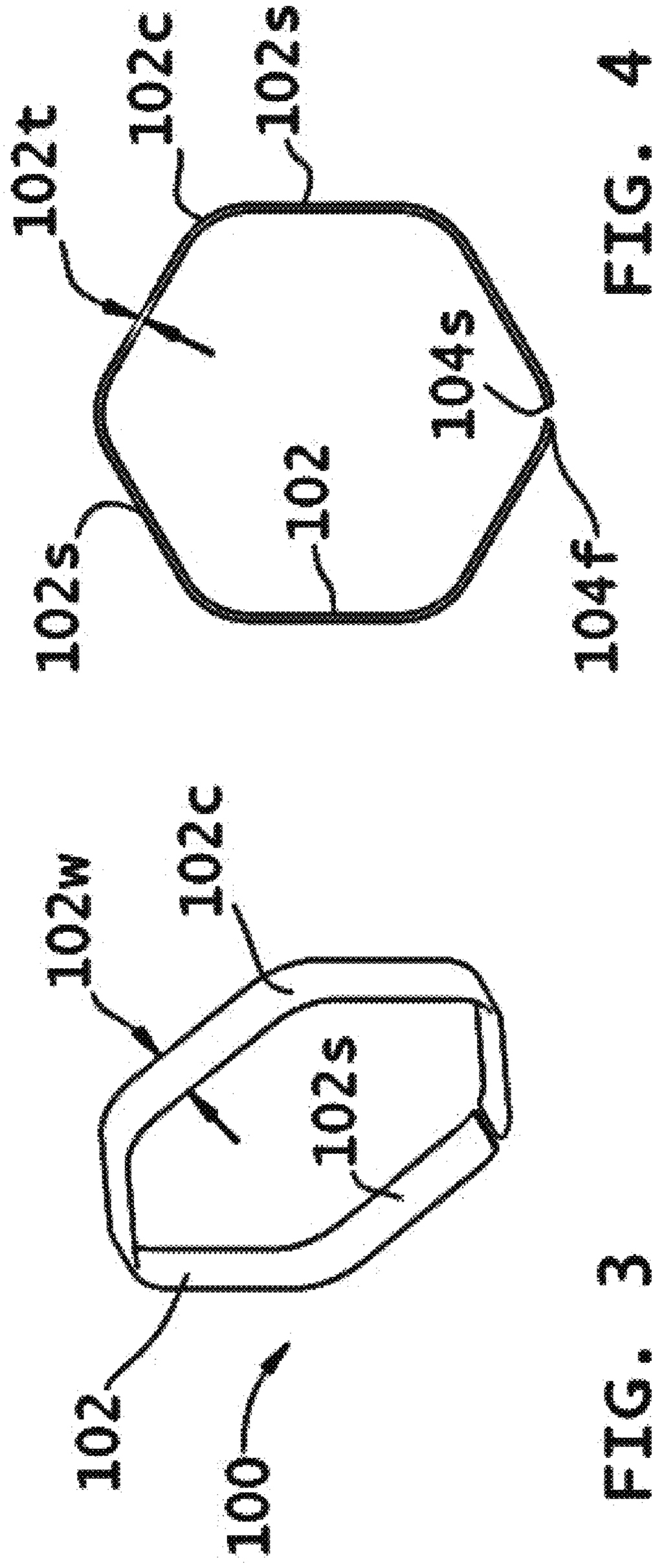

FIG. 4

FIG. 3

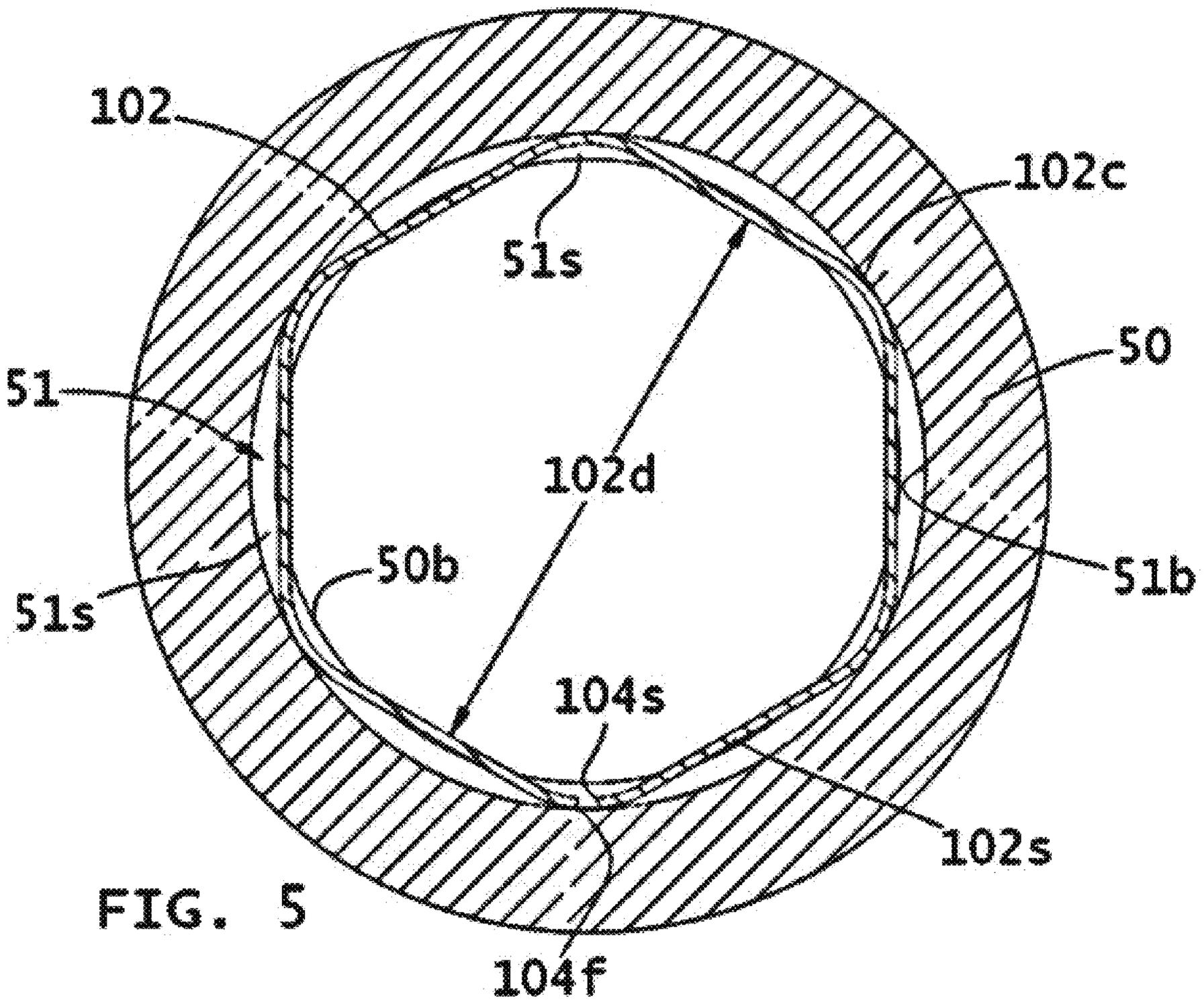

FIG. 5

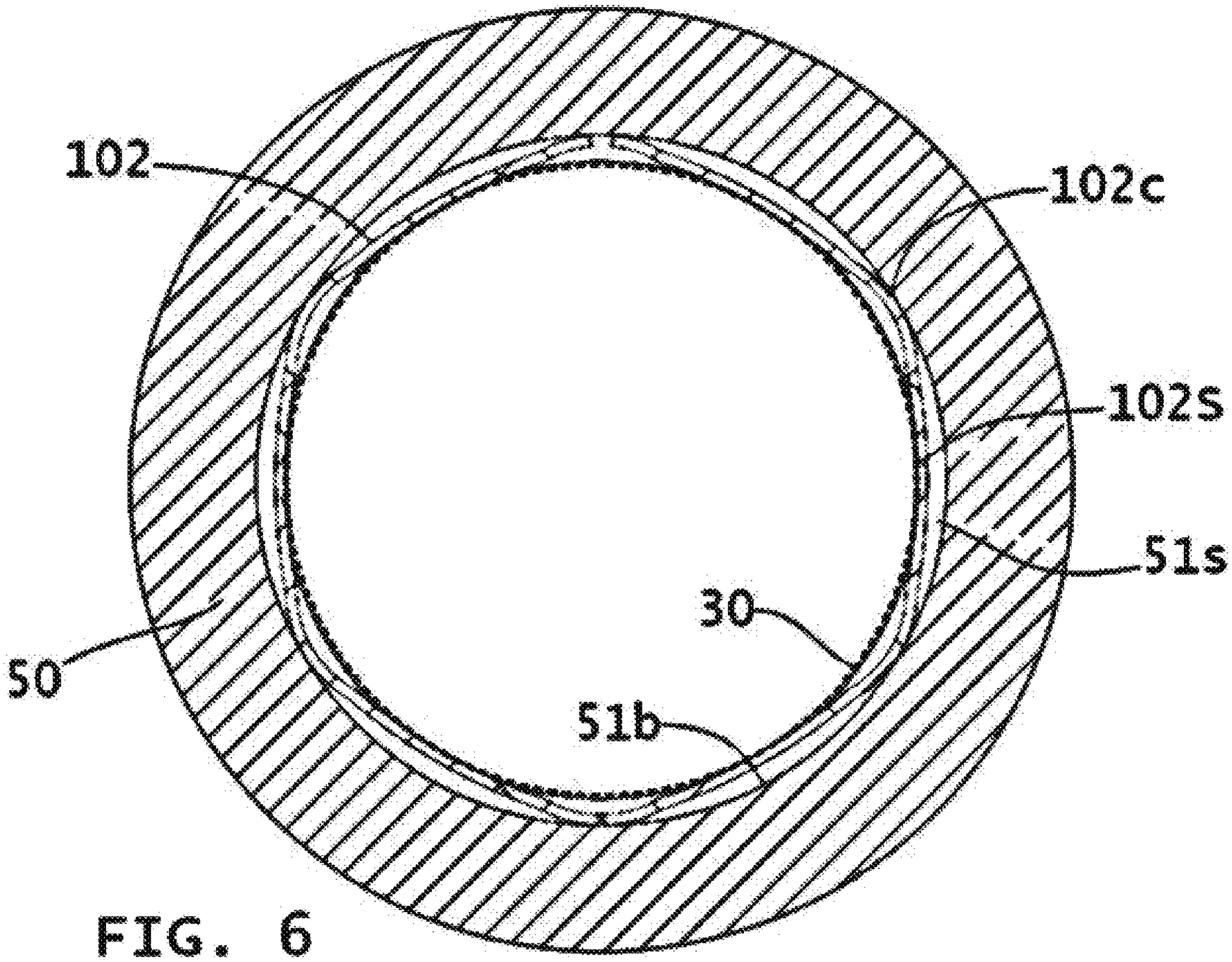

FIG. 6

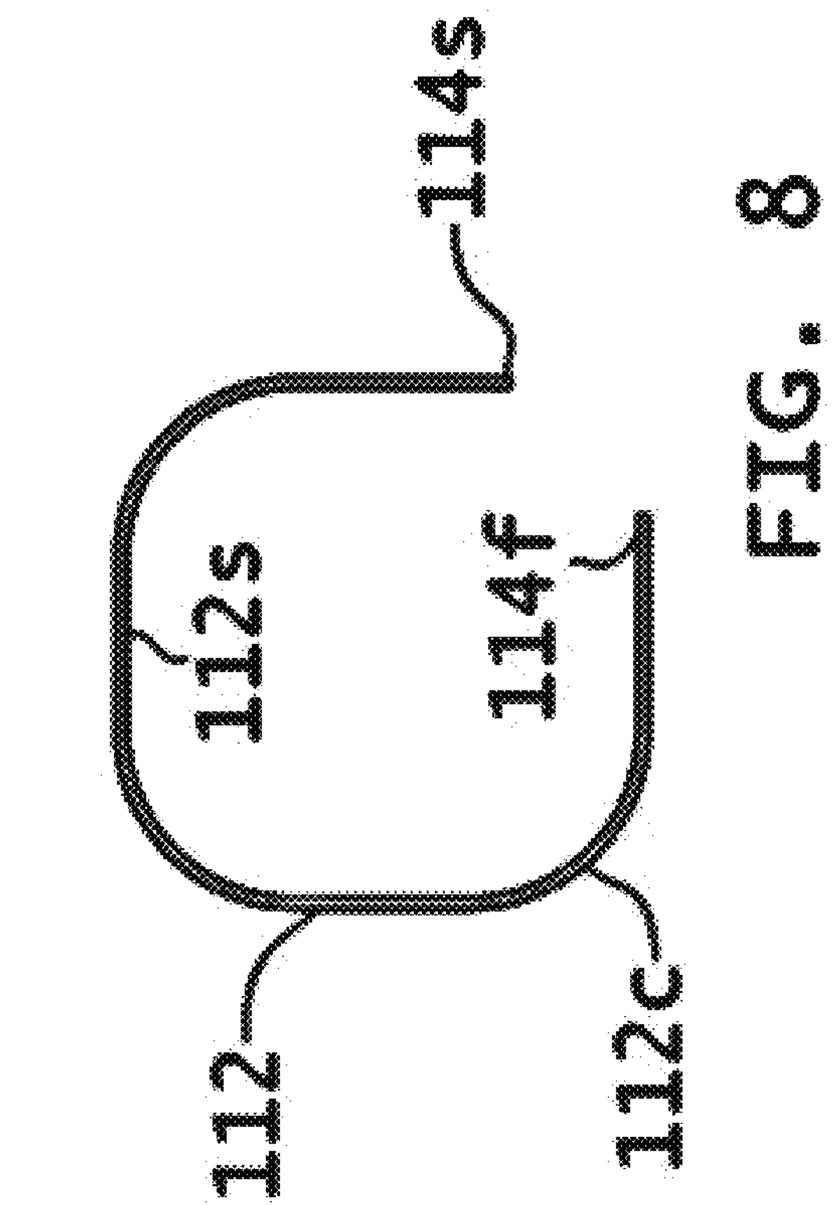

FIG. 8

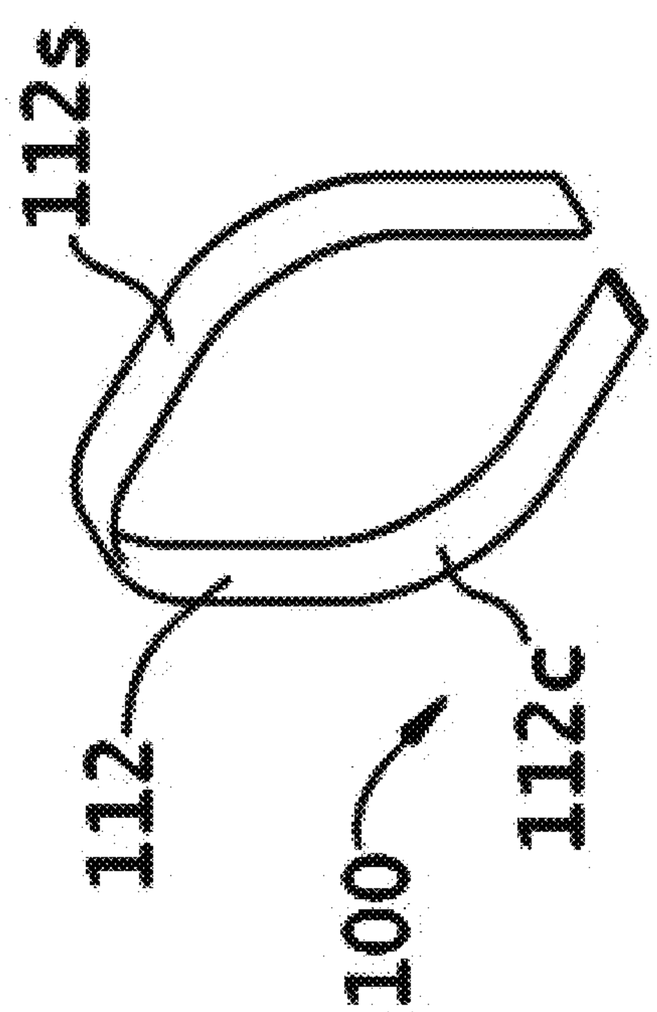

FIG. 7

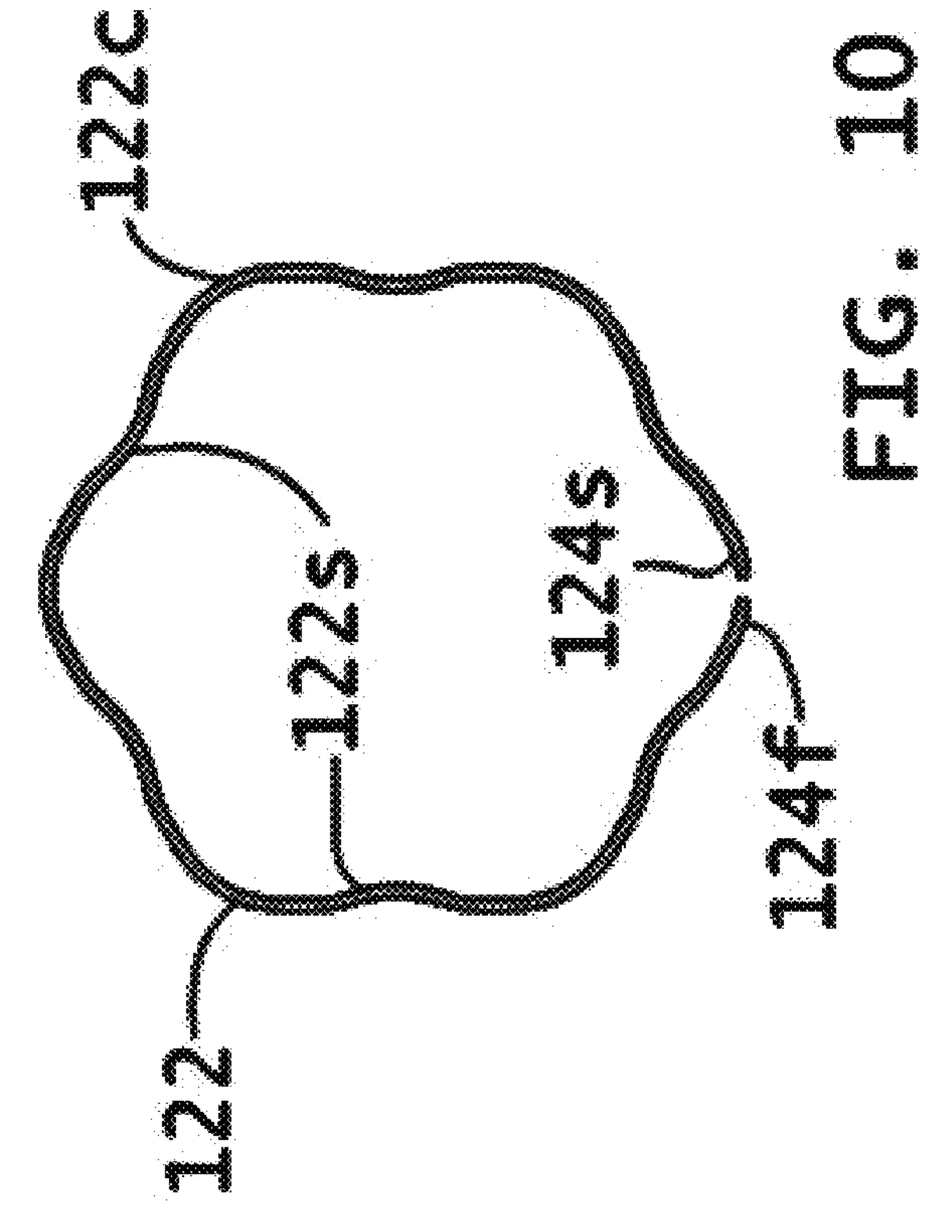

FIG. 10

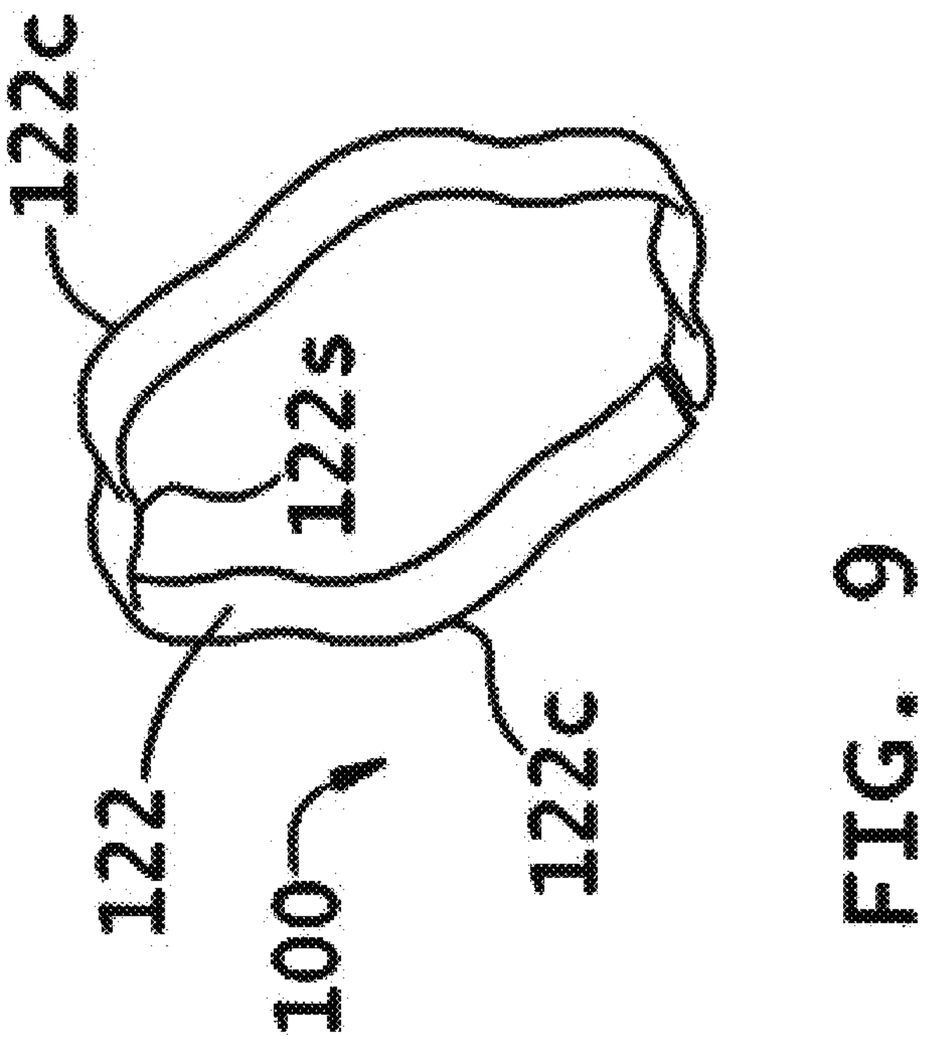

FIG. 9

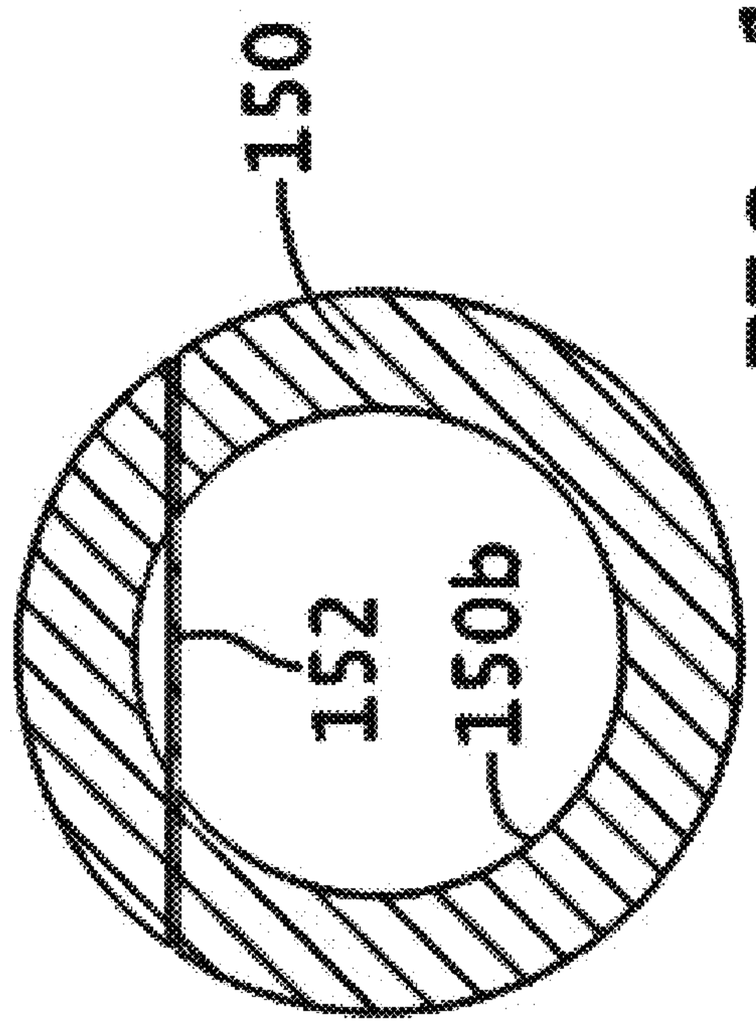

FIG. 12

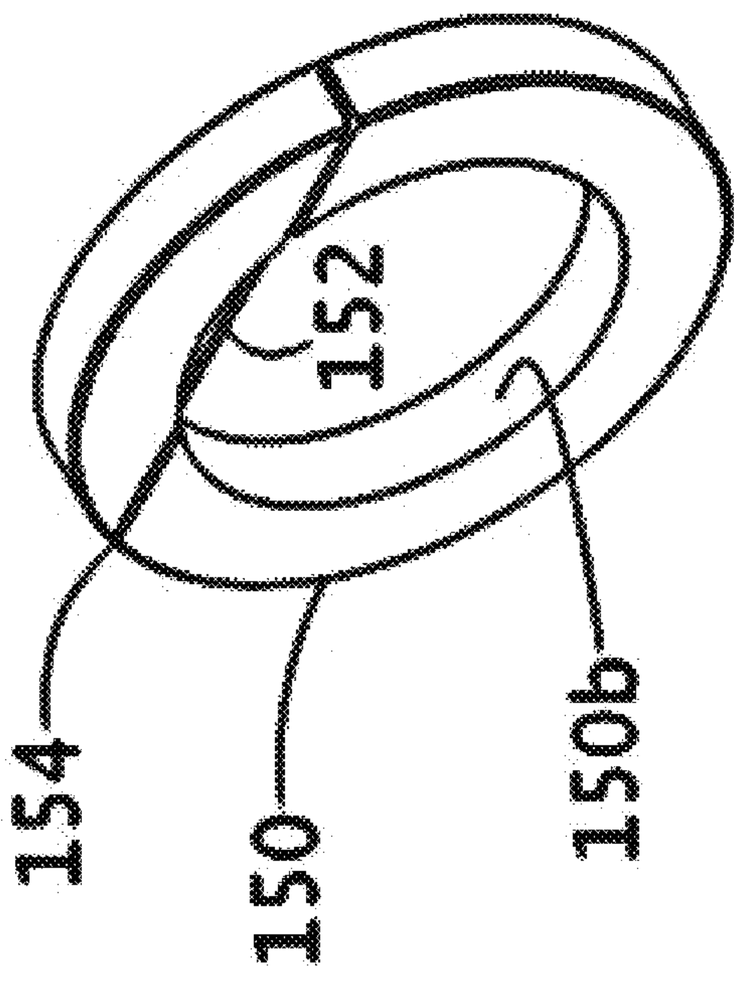

FIG. 11

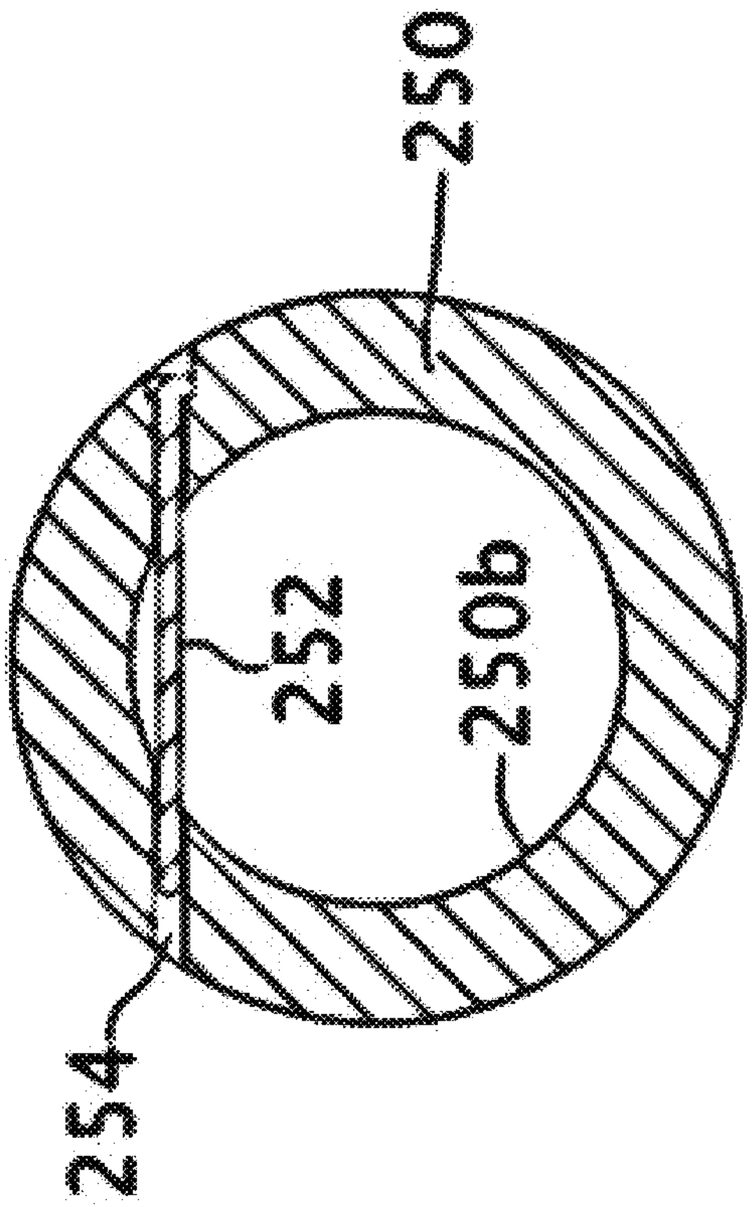

FIG. 14

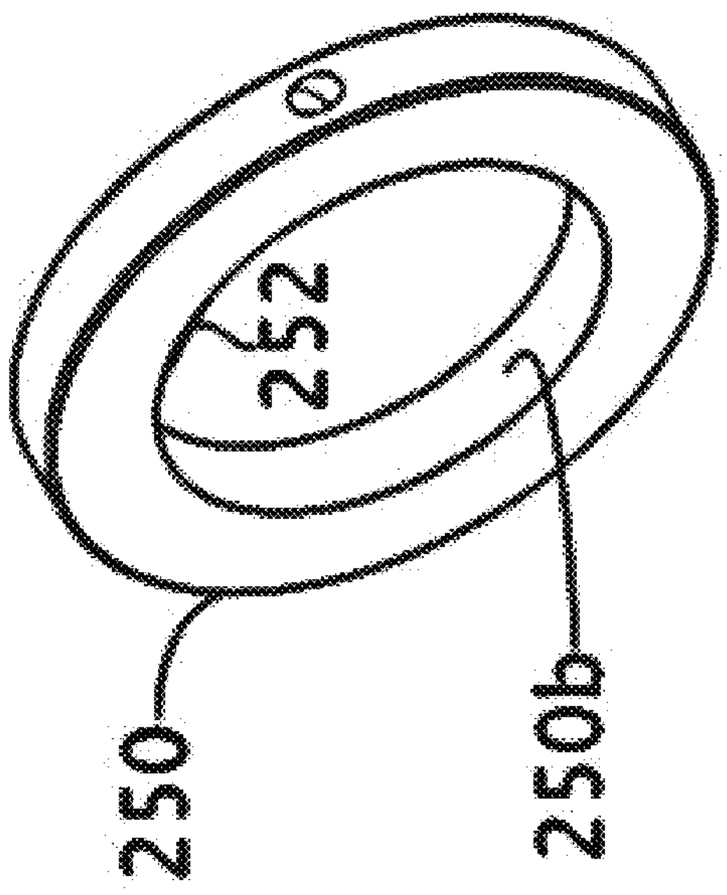

FIG. 13

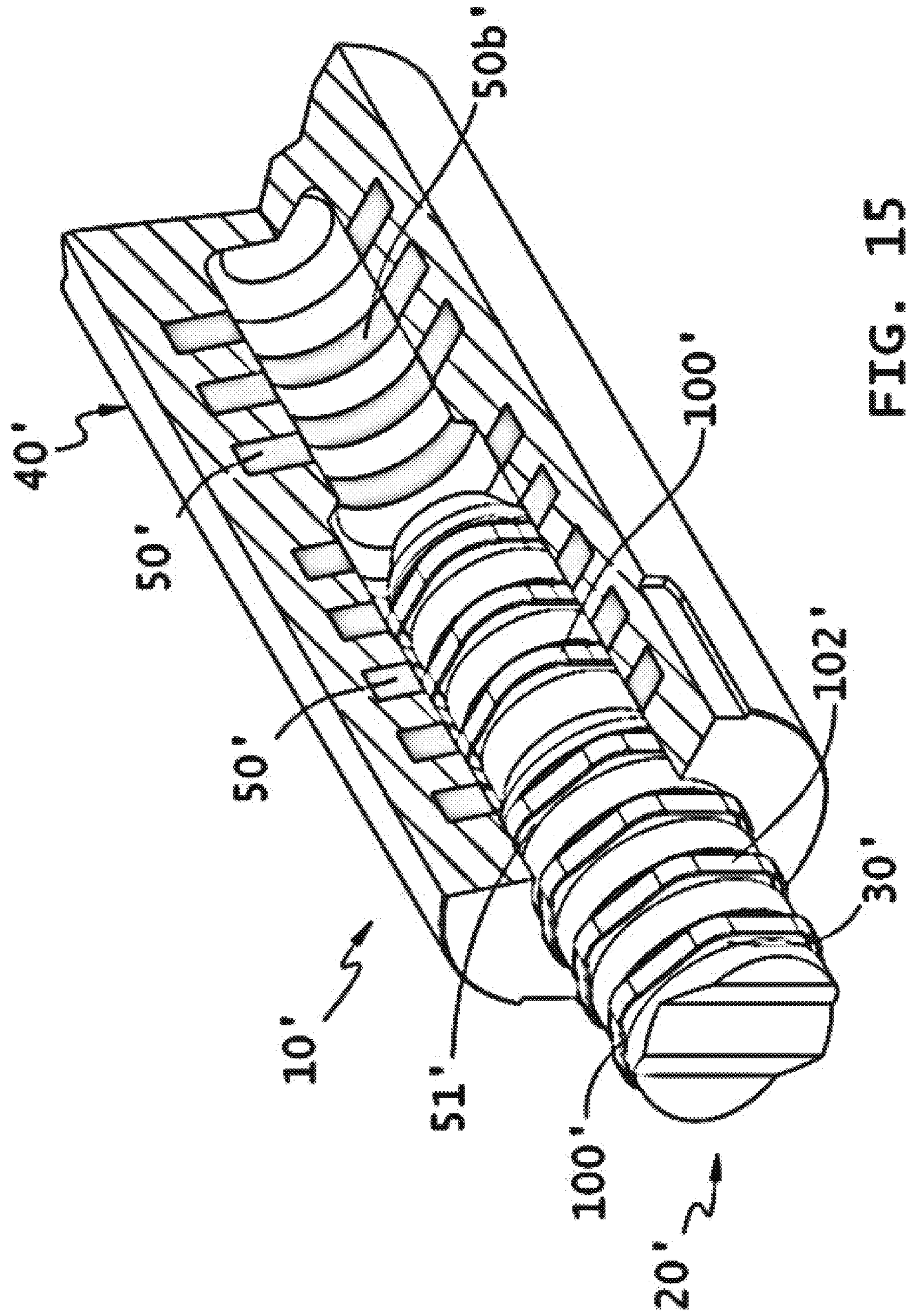

FIG. 15

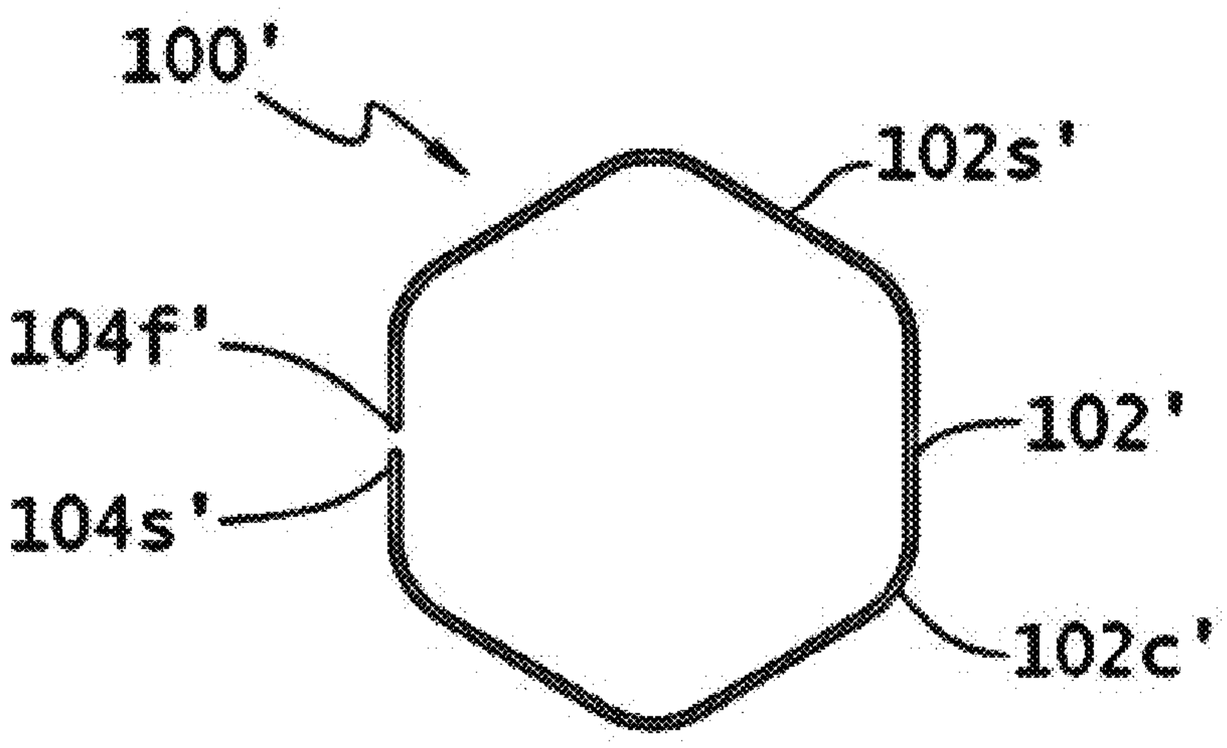

FIG. 16

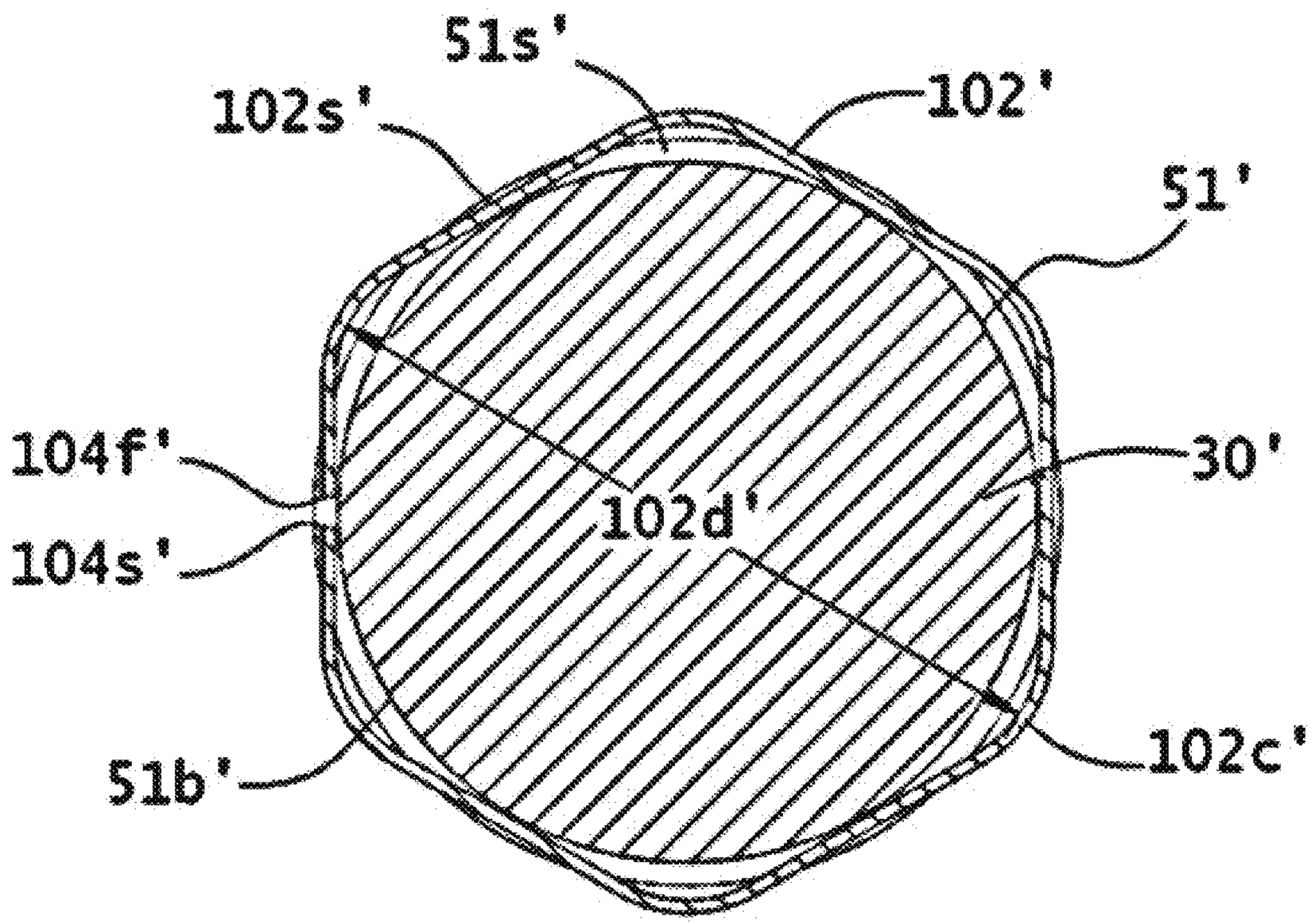

FIG. 17

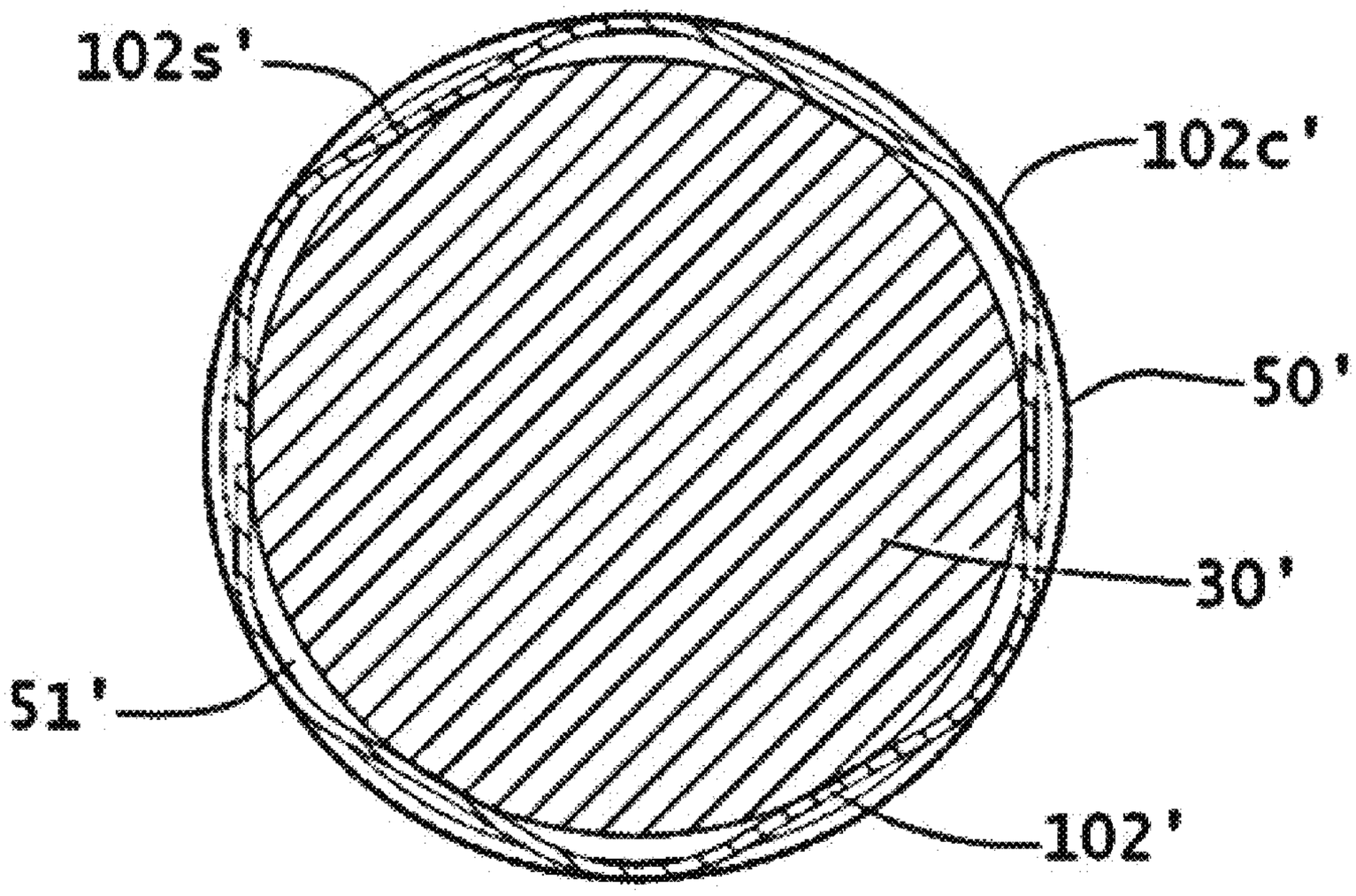

FIG. 18

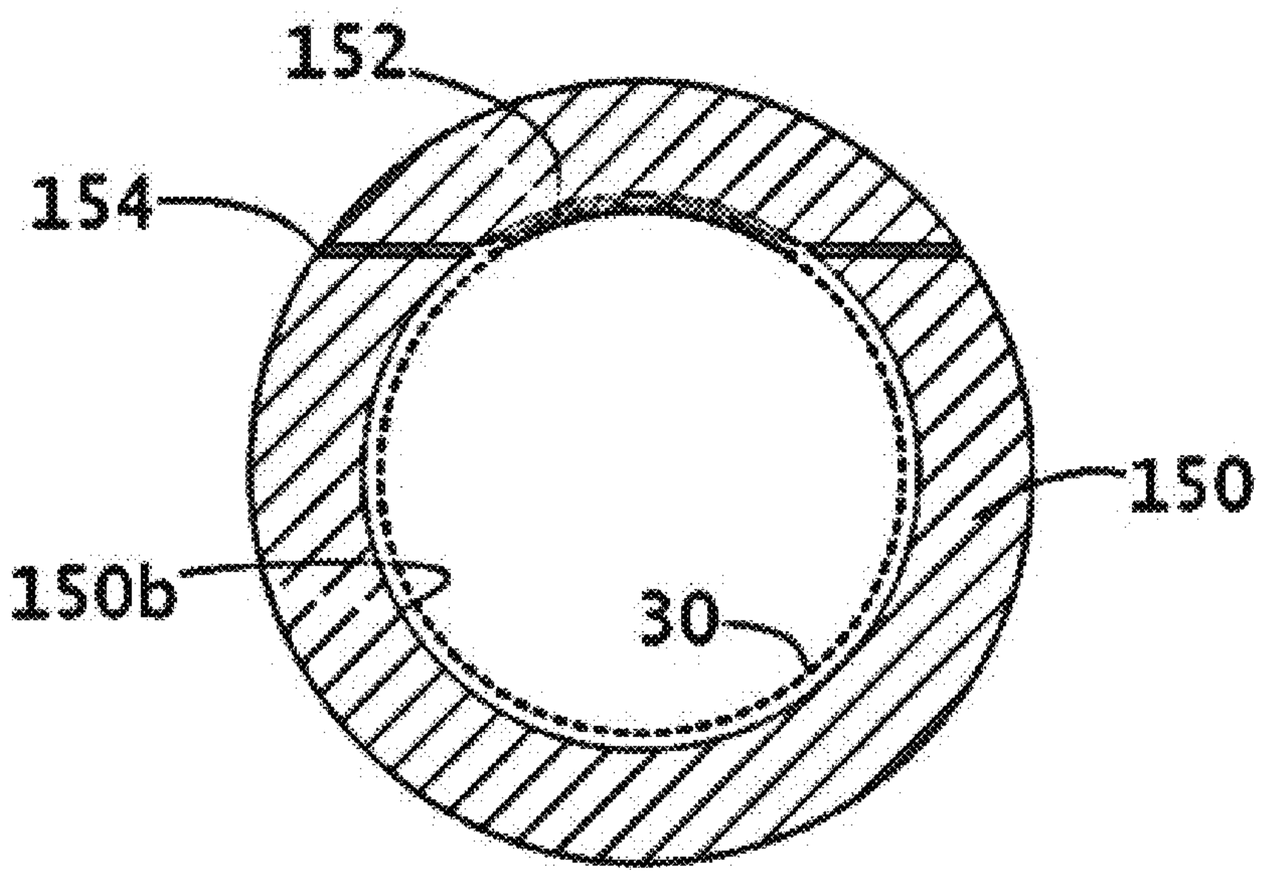

FIG. 19

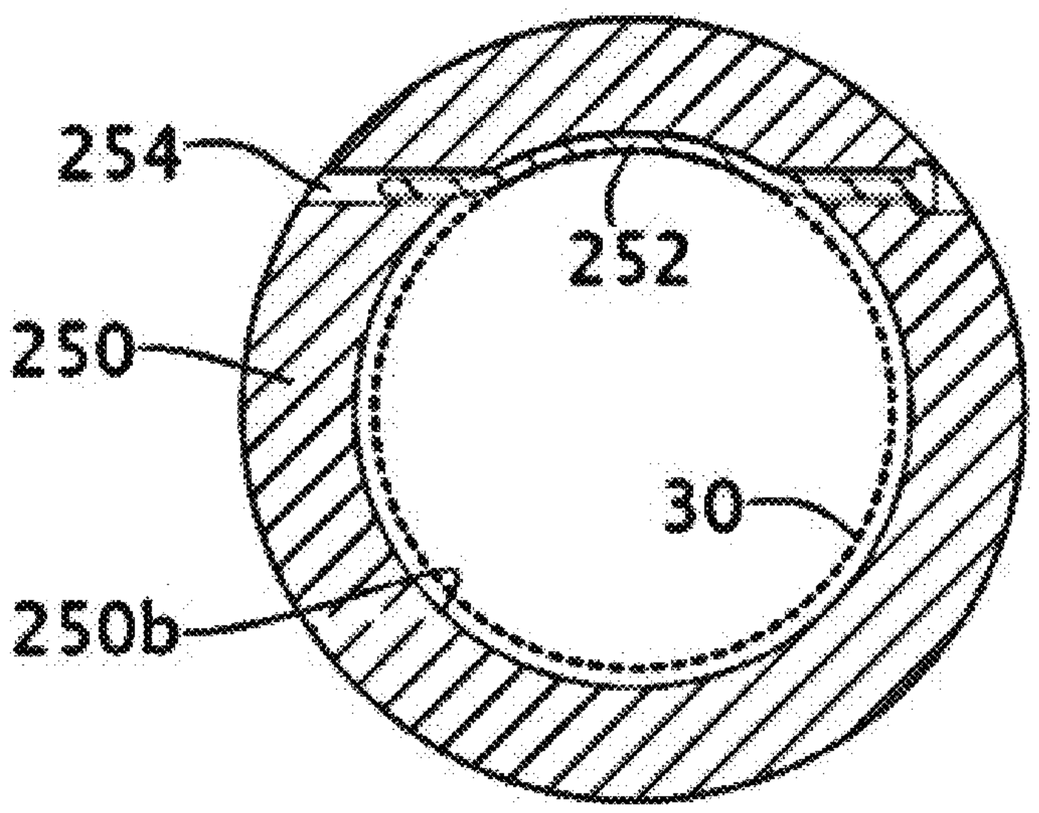

FIG. 20

MULTI-CONDUCTOR ROTARY CONNECTOR

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a divisional application of U.S. application Ser. No. 16/864,643, filed May 1, 2020, which claims the benefit of U.S. Provisional Application Ser. No. 62/842,841, filed May 3, 2019, entitled "Multi-Conductor Rotary Connector." Applicant incorporates by reference herein application Ser. Nos. 16/864,643 and 62/842,841 in their entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention.

The present invention relates generally to electrical, multiple conductor rotary connectors, and more specifically to the contacts for electrical, multiple conductor rotary connectors.

2. Description of the Related Art.

Electrical rotary connectors typically include a male assembly and a female assembly that engage one another and permit rotation of the male and female assemblies with respect to one another. Oftentimes, the joining of the male and female assemblies will have relative rotation as a result of threaded members. Sometimes it is desirable, that upon mating of the male and female assemblies to one another, for relative rotation to exist between the two assemblies while maintaining the electrical contacts.

The male assembly is adapted to removably seat in the female assembly. The male assembly typically has at least two spaced conductor rings on an outer surface and the female assembly has a corresponding number of spaced conductor rings on an inner surface spaced so as to be juxtaposed with the male assembly conductor rings when the male assembly is seated in the female assembly.

Typically, a member often referred to as a contact or electrically-conductive contact is positioned in an annular space between the juxtaposed conductor rings to allow for connector make-up, manufacturing tolerances and to ensure electrical connectivity is maintained between each pair of juxtaposed conductor rings when the male and female assemblies are mated.

One type of contact used by Greene, Tweed & Company of Kulpsville, PA, is a multi-leaf spring contact. The multi-leaf spring contact is installed within the female assembly. Thin metal leaves are uniformly spaced around the conductor ring in the axial direction with a "free end" of the metal leaf facing the rear of the female assembly. A rubber O-ring is positioned beneath the "free end" to energize the thin leaf springs.

Some shortcomings with the O-ring energized multi-leaf spring contact are: the thin metal leaves are fragile and break easily; the thin metal leaves are easily snagged during cleaning with rags, etc. thus causing breakage and/or permanent damage; low conductor cross-sectional area limiting electrical current capacity; the O-ring energizers are subject to compression set at elevated temperatures; does not allow for unitized plastic molding around contacts due to many leak pathways; and not axially compact.

U.S. Pat. No. 7,052,297 titled "Rotary Connector having Removable and Replaceable Contacts," assigned to Wireline Technologies, Inc. of Houston, Tex., discloses a canted coil spring contact for rotary connectors. The objects of the invention in the '297 patent are to provide an electrically-conductive contact that is replaceable and that is easily and quickly replaced in the field without extensive disassembly of the rotary connector. Although canted coil springs are easily replaced, they are suspect/prone to having very low durability—especially in harsh operating conditions such as high temperature, high pressure environments, or when subjected to vibrational forces, or cyclical loading-experienced in many applications where rotary connectors are used. The canted coil spring often cracks during operation and is prone to getting snagged and dislodged when cleaning the connector. The canted coil spring may become dislodged during connection or disconnection of the coupler or due to allowable manufacturing tolerances of the connector which may result in slight misalignment of the mating connectors. The canted coil spring is not axially compact as it becomes ovoid when squeezed radially during mating of the rotary connector.

Another prior art rotary electrical connector includes spring-loaded pogo pin contacts. Pogo pins are subject to movement during shock and vibration thus causing potential electrical signal issues and mechanical damage. Pogo pins are prone to shearing during mating of connectors thus causing permanent damage. Other disadvantages with spring-loaded pogo pin contacts are: pogo pins are not replaceable; no unitized plastic molding around contacts is possible due to plastic invasion into back side of the pogo canister; and not radially or axially compact so connectors cannot be as compact.

It is desirable to have a rotary electrical connector that is durable, can withstand intense vibrations and is resistant to fatigue failure. It is further desirable that the connector is durable over numerous connect and disconnect cycles. It is further desirable that the rotary electrical connector is compact. It is further desirable that the rotary electrical connector can work in high temperature, high pressure (HTHP) environments, as for example in the oilfield. It is desirable that the contact has one or more of the following characteristics: high durability, high electrical current capacity, very high shock and vibration tolerance, and little likelihood of damage during maintenance and during connecting and disconnecting the rotary connector.

SUMMARY OF THE INVENTION

The preferred embodiments of the invention provide a rotary connector having a plug and a receptacle with high durability during operation, in addition to having very low likelihood of damage during maintenance. In the rare event that a contact is damaged, the contact is replaceable. The rotary connector has very high shock and vibration tolerance making it well-suited for use in extreme and difficult environments. The preferred embodiments provide a connector having high electrical current capacity. The rotary connector is radially and axially compact, thus allowing for a smaller form factor connector. At least some of the embodiments allow for unitized molded assembly.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

The aspects, features, and advantages of the embodiments of the invention mentioned above are described in more

detail by reference to the drawings, wherein like reference numerals represent like elements having the same basic function, in which:

FIG. **1** is cross-sectional view of a rotary connector according to a preferred embodiment of the present invention, showing a plug inserted in a receptacle;

FIG. **2** is a partial perspective view of the rotary connector of FIG. **1**, the perspective view having a portion of the receptacle removed and showing the plug partially within the receptacle;

FIG. **3** is a perspective view of an electrically-conductive contact according to a preferred embodiment of the invention;

FIG. **4** is a front view of the contact shown in FIG. **3**;

FIG. **5** is a cross-sectional view of the contact of FIGS. **3** and **4** received in a groove of a conductor ring in the receptacle, the contact shown in a relaxed position;

FIG. **6** is a cross-sectional view similar to FIG. **5**, showing the contact in a deformed position with the conductor ring of the plug shown in dashed lines;

FIG. **7** is a perspective view of a contact according to another embodiment of the invention;

FIG. **8** is a front view of the contact shown in FIG. **7**;

FIG. **9** is a perspective view of a contact according to another embodiment of the invention;

FIG. **10** is a front view of the contact shown in FIG. **9**;

FIG. **11** is a perspective view of an alternative embodiment of a receptacle conductor ring with a contact inserted into a slot in the conductor ring;

FIG. **12** is a front, cross-sectional view of the conductor ring and contact shown in FIG. **11**;

FIG. **13** is a perspective view of an alternative embodiment of the conductor ring with a contact inserted in a hole in the conductor ring;

FIG. **14** is a front, cross-sectional view of the conductor ring and contact shown in FIG. **13**;

FIG. **15** is a partial perspective view of an alternative embodiment of the rotary connector, the perspective view having a portion of the receptacle removed and showing the plug partially within the receptacle and with electrically-conductive contacts installed on the plug;

FIG. **16** is a front view of an embodiment of an electrically-conductive contact for installation on the plug; and

FIG. **17** is a cross-sectional view of the contact of FIG. **16** received in a groove of a conductor ring in the plug, the contact shown in a relaxed position;

FIG. **18** is a cross-sectional view similar to FIG. **17**, showing the contact in a deformed position with the conductor ring of the receptacle shown in dashed lines;

FIG. **19** is a cross-sectional view similar to FIG. **12**, showing the receptacle conductor ring with the contact in a deformed position and the plug conductor ring shown in dashed lines; and

FIG. **20** is a cross-sectional view similar to FIG. **14**, showing the receptacle conductor ring with the contact in a deformed position and the plug conductor ring shown in dashed lines.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

It should be understood at the outset that although illustrative implementations of one or more embodiments are described below, the disclosed assemblies, systems and methods may be implemented using any number of techniques, whether currently known or not yet in existence. The disclosure should in no way be limited to the illustrative implementations, drawings, and techniques described below, but may be modified within the scope of the appended claims along with their full scope of equivalents.

The following brief definition of terms shall apply throughout the application:

The phrases "in one embodiment," "according to one embodiment," and the like generally mean that the particular feature, structure, or characteristic following the phrase may be included in at least one embodiment of the present invention, and may be included in more than one embodiment of the present invention (importantly, such phrases do not necessarily refer to the same embodiment);

If the specification describes something as "exemplary" or an "example," it should be understood that refers to a non-exclusive example;

The terms "about" or "approximately" or the like, when used with a number, may mean that specific number, or alternatively, a range in proximity to the specific number, as understood by persons of skill in the field of the art;

If the specification states a component or feature "may," "can," "could," "should," "would," "preferably," "possibly," "typically," "optionally," "for example," "often," or "might" (or other such language) be included or have a characteristic, that particular component or feature is not required to be included or to have the characteristic. Such component or feature may be optionally included in some embodiment, or it may be excluded.

Embodiments of the invention will now be described with reference to the figures, in which like numerals reflect like elements throughout. The terminology used in the description presented herein is not intended to be interpreted in any restrictive or limited way, simply because it is being utilized in conjunction with the detailed description of certain specific embodiments of the invention. Furthermore, embodiments of the invention may include several novel features, no single one of which is solely responsible for its desirable attributes or which is essential to practicing the invention described herein.

Referring to FIG. **1**, a rotary connector, generally referred to as **10**, is shown having a plug **20** fully inserted within a receptacle **40**. The rotary connector **10** in FIG. **1** is an eight pin, stepped rotary connector. There are eight electrical conductor rings **30** of the plug **20** that are juxtaposed to and/or in substantially radial alignment with eight electrical conductor rings **50** of the receptacle **40** when the plug **20** is seated in the receptacle **40**. It is to be understood that each pair of opposing conductor rings **30**, **50** acts cooperatively to conduct electricity through the rotary connector **10**.

An electrical wire or conductive member W is routed from each conductor ring **30** within the plug **20** and exits the rear of the plug **20** or connects to a terminal at the rear of the plug **20**. Similarly, an electrical wire or conductive member W is routed from each conductor ring **50** within the receptacle **40** and exits the rear of the receptacle **40** or connects to a terminal at the rear of the receptacle **40**. For purposes of clarity, FIG. **1** shows only one wire W connected to one plug conductor ring **30** and one wire W connected to one receptacle conductor ring **50**. As is well understood in the art, each conductor ring **30** and **50** is connected to a separate wire or conductive member W which is accessible or exits at the rear of the plug **20** and receptacle **40**, respectively.

It is to be understood that the number of pairs of conductor rings **30**, **50** will depend on the number of electrical signals or pathways needed for the specific rotary connector **10**. Thus, while eight pairs of conductor rings are shown in FIG. **1**, this is merely for illustration and not limiting to the invention.

As stated above, the rotary connector **10** shown in FIG. **1** is a stepped rotary connector. The plug **20** has a stepped outer diameter and the receptacle **40** has a stepped inner diameter. It is to be understood that this is well known to those skilled in the art and often used when there are several pairs of conductor rings **30**, **50** in the rotary connector **10**. It is to be understood that the plug **20** and receptacle **40** of the present invention could both have a uniform diameter or both have a plurality of stepped diameters.

Referring to FIGS. **1** and **2**, the plug **20** includes an insulating body **22** having a head portion **24** and a tail portion **26**. The head portion **24** has a head diameter **24***d* and the tail portion **26** has a tail diameter **26***d*. A tapered transition **28** preferably joins the head portion **24** to the tail portion **26**. The tail diameter **26***d* is larger than the head diameter **24***d*. It is to be understood that the plug insulating body **22** may alternatively be of uniform diameter. The plug insulating body **22** is preferably made of a dielectric or non-electrically conductive material. One such suitable material is polyether ether ketone (PEEK). A forward end **27** of the plug insulating body **22** is preferably tapered or rounded to provide guidance.

With reference to FIG. **1**, the electrical conductor rings **30** of the plug **20** are preferably circular and have a smooth outer surface. FIG. **1** shows three conductor rings **30** on the head portion **24** and five on the tail portion **26**. The number of plug conductor rings **30** will depend on the number of electrical signals or pathways needed for the specific rotary connector **10**. The plug conductor rings **30** are separated from one another by a non-conducting ring, spacer or a portion of the plug insulating body **22** in the event the plug **20** is a molded assembly. The actual assembly of the plug **20** is not critical to the claimed invention. One of ordinary skill in the art is familiar with various ways of assembling the plug **20**.

The plug conductor rings **30** preferably have an outer diameter substantially equal to or slightly greater than the corresponding diameter of the adjacent portion of the plug insulating body **22** in the embodiment shown in FIGS. **1** and **2**. The plug conductor rings **30** on the head portion **24** are designated **30***h* and the plug conductor rings **30** on the tail portion **26** are designated **30***t*. The plug conductor rings **30** are made from an electrically conductive material, as for example, beryllium copper.

The receptacle **40** includes an insulating body **42** that is preferably substantially cylindrical and has a bore **44** open at a front end **46** of the receptacle **40**. The bore **44** is sized and shaped to correspond with the size and shape of the head and tail portions **24** and **26** of the plug **20**. The receptacle **40** includes a number of conductor rings **50** corresponding to the number of plug conductor rings **30**. The receptacle conductor rings **50** that are arranged and designed to align with the plug conductor rings **30***h* on the head portion **24** are designated **50***h* and those arranged and designed to align with the plug conductor rings **30***t* on the tail portion **26** are designated **50***t*. The receptacle conductor rings **50***h* preferably have an axial, circular inner bore **50***b* (FIG. **5**) with an inside diameter slightly greater than the head diameter **24***d* and the outside diameter of the head portion conductor rings **30***h*. Similarly, the receptacle conductor rings **50***t* preferably have an axial, circular inner bore with an inside diameter slightly greater than the tail diameter **26***d* and the outside diameter of the tail portion conductor rings **30***t*. The receptacle conductor rings **50** are made from an electrically conductive material, as for example, beryllium copper.

In a preferred embodiment as shown in FIGS. **1** and **2**, a radially inward-facing groove **51**, preferably annular, is made in the receptacle conductor rings **50** for at least partially receiving an electrically-conductive contact **100**. Preferably, the inward-facing groove **51** is recessed radially outward of the inner bore **50***b* of the receptacle conductor rings **50**. The contacts **100** are shown in the grooves **51** in FIG. **2**. The electrically-conductive contacts **100** are made from an electrically conductive material.

In some embodiments of the present invention, the electrically-conductive contact **100** has a generally annular profile defining an opening. FIGS. **3** and **4** show a preferred design for the electrically-conductive contact **100**. FIGS. **3** and **4** show a generally polygonal-shaped contact **102** having arcuate portions or rounded corners or vertices **102***c* and generally straight segments **102***s*. The generally polygonal-shaped contact **102** shown in FIGS. **3** and **4** includes six substantially straight segments **102***s* joined by rounded corners **102***c* defining an opening within the generally polygonal-shaped contact **102**. Preferably, the generally polygonal-shaped contact **102** is discontinuous and has first and second ends **104***f* and **104***s*, respectively. The contact **102** shown in FIGS. **3** and **4** is the contact **100** shown in the receptacle **40** in FIG. **2**, although other embodiments of the electrically-conductive contact **100** could be used. Preferably, the first and second ends **104***f*, **104***s* are located at a rounded corner **102***c* when the contact **102** is to be installed in the receptacle **40** so that the ends **104***f*, **104***s* are in the groove **51** where they are unlikely to snag on anything.

FIG. **5** shows a cross-sectional view of the six-sided polygonal-shaped contact **102** received within the groove **51** of the receptacle conductor ring **50**. The groove **51** preferably has a pair of sidewalls **51***s* (only one shown) joined by a groove base **51***b* defining a groove width and a groove depth. Preferably, the sidewalls **51***s* extend radially outward from the inner bore **50***b* to the groove base **51***b* and the axial distance between the sidewalls **51***s* defines the groove width. Preferably, the groove width is in the range of about 0.001" to 0.015" wider than the contact width **102***w*. The groove depth is defined by the radial length of the sidewall **51***s*.

The contact **102** in FIG. **5** is in a relaxed position and has a relaxed inscribed diameter **102***d*. The generally straight segments **102***s* in the relaxed position define the relaxed inscribed diameter **102***d*. For the contact **102** shown in FIG. **5**, the relaxed inscribed diameter **102***d* is the shortest distance between oppositely facing generally straight segments **102***s*. At least a portion, typically a mid-portion, of the generally straight segments **102***s* is positioned outside of the groove **51** in the relaxed position as shown in FIG. **5**. Stated another way, the relaxed inscribed diameter **102***d* is smaller than the inside diameter of the receptacle conductor ring **50**. Preferably, the relaxed inscribed diameter **102***d* is smaller than the outer diameter of the corresponding plug conductor ring **30**.

Still referring to FIG. **5**, the contact **102** is in the relaxed position when the plug **20** is uncoupled from the receptacle **40** and when the plug **20** is not juxtaposed or contacting the contact **102**. The first and second ends **104***f* and **104***s* of the generally polygonal-shaped contact **102** are adjacent the groove base **51***b* and preferably have an edge portion contacting the groove base **51***b*. Preferably, each of the rounded corners **102***c* are in contact with the groove base **51***b* when in the relaxed position.

FIG. **6** is representative of when the plug **20** and receptacle **40** are fully joined or coupled together and the contact **102** is in an elastically deformed position. The outer surface of the plug conductor ring **30** is shown in dashed lines in FIG. **6**. Since the outer diameter of the plug conductor ring **30** is preferably at least slightly larger than the relaxed

inscribed diameter **102***d* of the contact **102**, the juxtaposed plug conductor ring **30** forces the straight segments **102***s* to bend slightly outwardly such that the contact **102** is slightly more circular. As shown in FIG. **6**, the elastically deformed straight segments **102***s* provide a substantial amount of surface area contact with the outer surface of the plug conductor ring **30**. Additionally, the contact **102** concurrently retains substantial contact with the groove base **51***b*. It is also to be understood that a portion of the side surfaces of the contact **102** facing the groove sidewalls **51***s* will also likely be in contact with at least one of the sidewalls **51***s*. The contact **102** is sufficiently elastic such that electrical contact is achieved and maintained between the corresponding plug and receptacle conductor rings **30**, **50**, when the plug **20** and receptacle **40** are fully mated, yet when the plug **20** is disconnected or removed from the receptacle **40** the contact **102** remains in the groove **51** and returns to its relaxed position with an inscribed diameter **102***d* smaller than the outer diameter of the mating plug conductor ring **30**.

In the mated condition of the plug **20** and receptacle **40**, the plug conductor rings **30** are radially aligned, or substantially radially aligned, with corresponding receptacle conductor rings **50**.

It is to be understood that the size and shape of the groove **51** is dependent on the type of contact **100** used, in addition to other design factors. Referring to FIGS. **3** and **4**, the contact **102** has a width **102***w* and a thickness **102***t*. The groove width, defined by the distance between the sidewalls **51***s*, is preferably slightly wider than the contact width **102***w*. Following are some representative dimensions for the groove **51** and contact **102** merely for exemplary purposes to illustrate an embodiment. In this example, the contact **102** has a width **102***w* of 0.060" (inches) and a thickness **102***t* of 0.008" and the groove **51** has a width of 0.064" and a depth in the range of 0.016" to 0.027" depending on various factors. Preferably, the dimensions are such that the contact **102** is securely positioned within the groove **51** and remains elastic.

The preferred embodiment of the rotary connector provides the following advantages:

High durability during operation as well as very low likelihood of damage during maintenance;

Contact is replaceable in rare instance of damage;

High electrical current capacity;

Very high shock and vibration tolerance;

Radially and axially compact thus allowing for a smaller form factor connector; and

Allows for unitized molded assembly.

FIGS. **7-14** illustrate other embodiments of electrically-conductive contacts **100**. It is to be understood that the following embodiments of electrically-conductive contacts **100** include all or some of the above advantages.

The contact **100** shown in FIGS. **7** and **8** is another generally polygonal-shaped contact, generally referred to as **112**, having rounded corners or vertices **112***c*. The generally polygonal-shaped contact **112** shown in FIGS. **7** and **8** includes rounded corners **112***c* separated by four generally straight segments **112***s*. Preferably, the generally polygonal-shaped contact **112** is discontinuous and has first and second ends **114***f* and **114***s*, respectively. Preferably, the first and second ends **114***f* and **114***s* are located such that they would remain within an inwardly facing groove **51** and contact the groove base **51***b*.

FIGS. **9** and **10** show a generally marcel-shaped contact **122** having a plurality of rounded external corners or vertices **122***c*. The generally marcel-shaped contact **122** includes a plurality of rounded external corners **122***c* separated by generally wavy segments **122***s*. Preferably, the generally marcel-shaped contact **122** is discontinuous and has first and second ends **124***f* and **124***s*, respectively. Preferably, the first and second ends **124***f* and **124***s* are located such that they would remain within an inwardly-facing groove **51** and contact the groove base **51***b*.

FIGS. **11** and **12** show an alternative receptacle conductor ring **150** having an axial inner bore **150***b*. The axial inner bore **150***b* may be a continuous axial bore, without the need to have an inwardly-facing groove. A slot **154** extends transversely through the conductor ring **150** and intersects the inner bore **150***b* at two locations. An electrically-conductive contact **152** in the form of a flexible beam is inserted into the slot and within a portion of the inner bore **150***b* as shown in FIG. **12**. The contact **152** has a relaxed position in which the contact **152** is a substantially straight member passing within the inner bore **150***b* of the receptacle conductor ring **150** as shown in FIGS. **11** and **12**.

FIG. **19** is representative of when the plug **20** and receptacle **40** are fully joined or coupled together and the contact **152** is in an elastically deformed position. The outer surface of the plug conductor ring **30** is shown in dashed lines. The outer diameter of the plug conductor ring **30** is sized so that upon mating of the plug with the receptacle, the mating plug conductor ring **30** contacts and elastically deforms the contact **152** within the inner bore **150***b*. The contact **152** is sufficiently elastic that electrical contact is achieved when deformed by plug connector ring **30**, yet when disconnected from the plug the contact **152** returns to its relaxed straight condition. The contact **152** may have a polygonal or rounded cross-section. In this alternative, the contact **152** is replaceable if the receptacle **40** is assembled, for example, by stacking insulator rings and conductor rings.

FIGS. **13** and **14** show another alternative receptacle conductor ring **250** similar to the one shown in FIGS. **11** and **12**. FIGS. **13** and **14** show an alternative receptacle conductor ring **250** having an axial inner bore **250***b*. The axial inner bore **250***b* may be a continuous axial bore, without the need to have an inwardly-facing groove. A transverse bore **254** extends through the conductor ring **250** and intersects the axial inner bore **250***b* at two locations. An electrically-conductive contact **252** is inserted into the transverse bore **254** in the conductor ring **250** and within a portion of the axial inner bore **250***b* as shown in FIG. **14**. The contact **252** has a relaxed position in which the contact **252** is a substantially straight member passing within the axial inner bore **250***b* of the receptacle conductor ring **250** as shown in FIG. **14**.

FIG. **20** is representative of when the plug **20** and receptacle **40** are fully joined or coupled together and the contact **252** is in an elastically deformed position. The outer surface of the plug conductor ring **30** is shown in dashed lines. The outer diameter of the plug conductor ring **30** is sized so that upon mating of the plug **20** with the receptacle **40**, the mating plug conductor ring **30** contacts and elastically deforms the contact **252** within the inner bore **250***b*. The contact **252** is sufficiently elastic that electrical contact is achieved when deformed by plug connector ring **30**, yet when disconnected from the plug the contact **252** returns to its relaxed straight condition. Preferably, the contact **252** has a circular cross-section. If the contact **252** is press-fitted in the conductor ring **250**, this embodiment may be used in a molded assembly. If the contact **252** is not press-fitted and the receptacle can be disassembled, the contact **252** may be replaceable.

FIG. **15** shows an alternative embodiment of the rotary connector, generally designated **10'**, which is similar in

many respects with the rotary connector **10** shown in FIGS. **1** and **2**. The primary difference is that the rotary connector **10'** has the electrically-conductive contacts **100'** installed on the plug conductor rings **30'**, preferably in outwardly-facing grooves **51'** and the receptacle conductor rings **50'** have a smooth inner bore **50***b*'. The contact **102'** shown is similar in shape to the contact **102** of FIGS. **3** and **4**. The contact **102'** is discontinuous and preferably has first and second ends **104***f*' and **104***s*' at a mid-portion of a generally straight segment **102***s*' as shown in FIG. **16**.

FIG. **17** shows a cross-sectional view of the six-sided polygonal-shaped contact **102'** received within the groove **51'** of the plug conductor ring **30'**. The groove **51'** preferably has a pair of sidewalls **51***s*' (only one shown) joined by a groove base **51***b*' defining a groove width and a groove depth. The contact **102'** is in a relaxed position and has a relaxed inscribed diameter **102***d*'. The rounded corners **102***c*' in the relaxed position define the relaxed inscribed diameter **102***d*'. For the contact **102'** shown in FIG. **17**, the relaxed inscribed diameter **102***d*' is the longest distance between oppositely facing rounded corners **102***c*'. At least a portion, typically a mid-portion, of the rounded corners **102***c*' is positioned outside of the groove **51'** in the relaxed position as shown in FIG. **17**. Preferably, the relaxed inscribed diameter **102***d*' is larger than the inside diameter of the receptacle conductor ring **50'**. Preferably, the relaxed inscribed diameter **102***d*' is larger than the outside diameter of the corresponding plug conductor ring **30'**.

Still referring to FIG. **17**, the contact **102'** is in the relaxed position when the plug **20'** is uncoupled from the receptacle **40'** and when the receptacle **40'** is not juxtaposed or contacting the contact **102'**. The first and second ends **104***f*' and **104***s*' of the generally polygonal-shaped contact **102'** are preferably adjacent the groove base **51***b*' and preferably have an edge portion contacting the groove base **51***b*'. Preferably, a portion of each of the generally straight segments **102***s*' is in contact with the groove base **51***b*' when in the relaxed position.

FIG. **18** is representative of when the plug **20'** and receptacle **40'** are fully joined or coupled together and the contact **102'** is in an elastically deformed position. The inner surface of the receptacle conductor ring **50'** is shown in dashed lines. Since the inner diameter of the receptacle conductor ring **50'** is preferably at least slightly smaller than the relaxed inscribed diameter **102***d*' of the contact **102'**, the juxtaposed receptacle conductor ring **50'** forces the contact **102'** to become slightly more circular. As shown in FIG. **18**, the elastically deformed contact **102'** provides a substantial amount of surface area contact with the inner surface of the receptacle conductor ring **50'** while concurrently retaining substantial contact with the groove base **51***b*'. It is also to be understood that a portion of the side surfaces of the contact **102'** facing the groove sidewalls **51***s*' will also likely be in contact with at least one of the sidewalls **51***s*'. The contact **102'** is sufficiently elastic such that electrical contact is achieved and maintained between the corresponding plug and receptacle conductor rings **30'**, **50'**, when the plug **20'** and receptacle **40'** are fully mated, yet when the plug **20'** is disconnected or removed from the receptacle **40'** the contact **102'** remains in the groove **51'** and returns to its relaxed position with an inscribed diameter **102***d*' larger than the inner diameter of the mating receptacle conductor ring **50'**.

It is to be understood that the groove in the conductor ring in the above described embodiments will vary based on the size, shape and type of contact. The groove is designed to create the required force for each size of contact.

It is to be understood that the cross-section shapes of the contacts in the figures are not limited to the shape illustrated (i.e., rectangular) but may comprise other shapes including, but not limited to, round.

It is to be understood that insulators between adjacent contacts can be discrete pieces or a unitized molded system. Additionally, the system allows for optional hermetic sealing of electrical connector within mating housings.

An analysis of the force required for the contact **102** shown in FIGS. **3** and **4** to yield in bending where the width **102***w* is **0.06"**, thickness **102***t* is **0.008"** and length is 0.17" results in a force of 1.58 Newtons or 0.355 lbs. Comparable analysis for the multi-leaf spring and the canted coil spring designs described in the Background of the Invention result in yielding with forces significantly lower than for the preferred embodiment as shown below:

Design	Force (Newtons)	Force (Pounds)
FIGS. 3-4 Embodiment	1.58	0.355
Multi-Leaf Spring	0.075	0.017
Canted Coil Spring	0.175	0.039

The foregoing disclosure and description of the invention are illustrative and explanatory thereof, and various changes in the size, shape and materials, as well as in the details of the illustrated construction, may be made without departing from the spirit of the invention. The present embodiment is, therefore, to be considered as merely illustrative and not restrictive, the scope of the invention being indicated by the claims rather than the foregoing description, and all changes which come within the meaning and range of equivalence of the claims are therefore intended to be embraced therein.

While the invention has been described in detail above with reference to specific embodiments, it will be understood that modifications and alterations in the embodiments disclosed may be made by those practiced in the art without departing from the spirit and scope of the invention. All such modifications and alterations are intended to be covered. In addition, all publications cited herein are indicative of the level of skill in the art and are hereby incorporated by reference in their entirety as if each had been individually incorporated by reference and fully set forth.

We claim:

1. An electrical connector (**10**) comprising:

a) a plug (**20**) comprising:

i) an electrically-insulating plug body (**22**);

ii) a plug conductor ring (**30**); and

iii) an electrically-conductive member (W) connected to the plug conductor ring (**30**) within the plug body (**22**) and exiting an end of the plug body (**22**); and

b) a receptacle (**40**) comprising:

i) an electrically-insulating receptacle body (**42**);

ii) a receptacle conductor ring (**150**, **250**), the receptacle conductor ring (**150**, **250**) having an axial inner bore (**150***b*, **250***b*) and a transverse opening (**154**, **254**) intersecting the axial inner bore (**150***b*, **250***b*) at two locations;

iii) an electrically-conductive member (W) connected to the receptacle conductor ring (**150**, **250**) and exiting an end of the receptacle body (**40**);

iv) an electrically-conductive contact (**152**, **252**) received in the transverse opening (**154**, **254**) and having a relaxed position and an elastically-deformed position, wherein in the relaxed position the electrically-conductive contact (**152**, **252**) is a sub-

stantially straight member and extends transversely within the axial inner bore (**150***b*, **250***b*) of the receptacle conductor ring (**150**, **250**), and

in the elastically-deformed position, the electrically-conductive contact (**152**, **252**) is elastically deformed within the axial inner bore (**150***b*, **250***b*) by the plug conductor ring (**30**), the plug conductor ring (**30**) contacting the electrically-conductive contact (**152**, **252**)

and electrical contact is achieved between the plug conductor ring (**30**) and the receptacle conductor ring (**150**, **250**), and

upon removal of the plug conductor ring (**30**) from contact with the electrically-conductive contact (**152**, **252**), the electrically-conductive contact (**152**, **252**) returns to its relaxed position.

2. The electrical connector (**10**) of claim **1**, wherein the electrically-conductive contact (**152**) has a polygonal cross-section.

3. The electrical connector (**10**) of claim **1**, wherein the electrically-conductive contact (**152**) has a circular cross-section.

4. The electrical connector (**10**) of claim **1**, wherein the transverse opening is a slot (**154**) and the electrically-conductive contact (**152**) is a flexible beam.

5. The electrical connector (**10**) of claim **1**, wherein the transverse opening is a transverse bore (**254**) and the electrically-conductive contact (**252**) has a circular cross-section.

6. The electrical connector (**10**) of claim **5**, wherein the electrically-conductive contact (**252**) is press-fitted in the transverse bore (**254**) of the conductor ring (**250**).

7. An electrical connector (**10**) comprising:

a) a plug (**20**) comprising:

i) an electrically-insulating plug body (**22**);

ii) a plug conductor ring (**30**); and

iii) an electrically-conductive member (W) connected to the plug conductor ring (**30**) within the plug body (**22**) and exiting an end of the plug body (**22**); and

b) a receptacle (**40**) comprising:

i) an electrically-insulating receptacle body (**42**);

ii) a receptacle conductor ring (**150**) having an axial inner bore (**150***b*) and a transverse slot (**154**) in the receptacle conductor ring (**150**) interrupted by the axial inner bore (**150***b*) such that the transverse slot has two aligned transverse slot portions separated by the axial inner bore (**150***b*);

iii) an electrically-conductive member (W) connected to the receptacle conductor ring (**150**) and exiting an end of the receptacle body (**40**);

iv) an electrically-conductive contact (**152**) received in the two aligned transverse slot portions and having an electrically-conductive contact portion in the axial inner bore (**150***b*), the electrically-conductive contact (**152**) having a relaxed position and an elastically-deformed position,

wherein in the relaxed position the electrically-conductive contact (**152**) is a substantially straight member and extends transversely within the axial inner bore (**150***b*) of the receptacle conductor ring (**150**), and

in the elastically-deformed position, the electrically-conductive contact (**152**) is elastically deformed within the axial inner bore (**150***b*) by the plug conductor ring (**30**), the plug conductor ring (**30**) contacting the electrically-conductive contact (**152**) and electrical contact is achieved between the plug conductor ring (**30**) and the receptacle conductor ring (**150**), and

upon removal of the plug conductor ring (**30**) from contact with the electrically-conductive contact (**152**), the electrically-conductive contact (**152**) returns to its relaxed position.

8. The electrical connector (**10**) of claim **7**, wherein the electrically-conductive contact (**152**) has a polygonal cross-section.

9. The electrical connector (**10**) of claim **7**, wherein the electrically-conductive contact (**152**) has a circular cross-section.

10. The electrical connector (**10**) of claim **7**, wherein the electrically-conductive contact (**152**) is a flexible beam.

11. An electrical connector (**10**) comprising:

a) a plug (**20**) comprising:

i) an electrically-insulating plug body (**22**);

ii) a plug conductor ring (**30**); and

iii) an electrically-conductive member (W) connected to the plug conductor ring (**30**) within the plug body (**22**) and exiting an end of the plug body (**22**); and

b) a receptacle (**40**) comprising:

i) an electrically-insulating receptacle body (**42**);

ii) a receptacle conductor ring (**250**) having an axial inner bore (**250***b*) and a transverse bore (**254**) in the receptacle conductor ring (**250**) interrupted by the axial inner bore (**250***b*) such that the transverse bore (**254**) has two aligned transverse bore portions separated by the axial inner bore (**250***b*);

iii) an electrically-conductive member (W) connected to the receptacle conductor ring (**250**) and exiting an end of the receptacle body (**40**);

iv) an electrically-conductive contact (**252**) received in the two aligned transverse bore portions and having an electrically-conductive contact portion in the axial inner bore (**250***b*), the electrically-conductive contact (**252**) having a relaxed position and an elastically-deformed position,

wherein in the relaxed position the electrically-conductive contact (**252**) is a substantially straight member and extends transversely within the axial inner bore (**250***b*) of the receptacle conductor ring (**250**), and

in the elastically-deformed position, the electrically-conductive contact (**252**) is elastically deformed within the axial inner bore (**250***b*) by the plug conductor ring (**30**), the plug conductor ring (**30**) contacting the electrically-conductive contact (**252**) and electrical contact is achieved between the plug conductor ring (**30**) and the receptacle conductor ring (**250**), and

upon removal of the plug conductor ring (**30**) from contact with the electrically-conductive contact (**252**), the electrically-conductive contact (**252**) returns to its relaxed position.

12. The electrical connector (**10**) of claim **11**, wherein the electrically-conductive contact (**252**) has a circular cross-section.

13. The electrical connector (**10**) of claim **12**, wherein the electrically-conductive contact (**252**) is press-fitted in the transverse bore (**254**) of the conductor ring (**250**).

* * * * *

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(12) **United States Patent**
Carter et al.

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(45) **Date of Patent: *Feb. 21, 2023**

(54) **MULTI-CONDUCTOR ROTARY CONNECTOR**

(71) Applicant: **RAMPART PRODUCTS LLC**, Houston, TX (US)

(72) Inventors: **Sean W. Carter**, Houston, TX (US); **Michael A. Czuppon**, Houston, TX (US); **Edward J. Beshoory**, Houston, TX (US)

(73) Assignee: **RAMPART PRODUCTS LLC**, Houston, TX (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

This patent is subject to a terminal disclaimer.

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(Continued)

(51) **Int. Cl.**
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(Continued)

(52) **U.S. Cl.**
CPC ***H01R 13/17*** (2013.01); ***H01R 13/10*** (2013.01); ***H01R 13/111*** (2013.01); ***H01R 24/58*** (2013.01); ***H01R 39/64*** (2013.01); *H01R 13/187* (2013.01)

(58) **Field of Classification Search**
CPC H01R 13/187; H01R 13/10; H01R 13/17; H01R 39/64; H01R 24/58; H01R 13/111; H01R 13/5202; H01R 39/00; H01R 24/38
See application file for complete search history.

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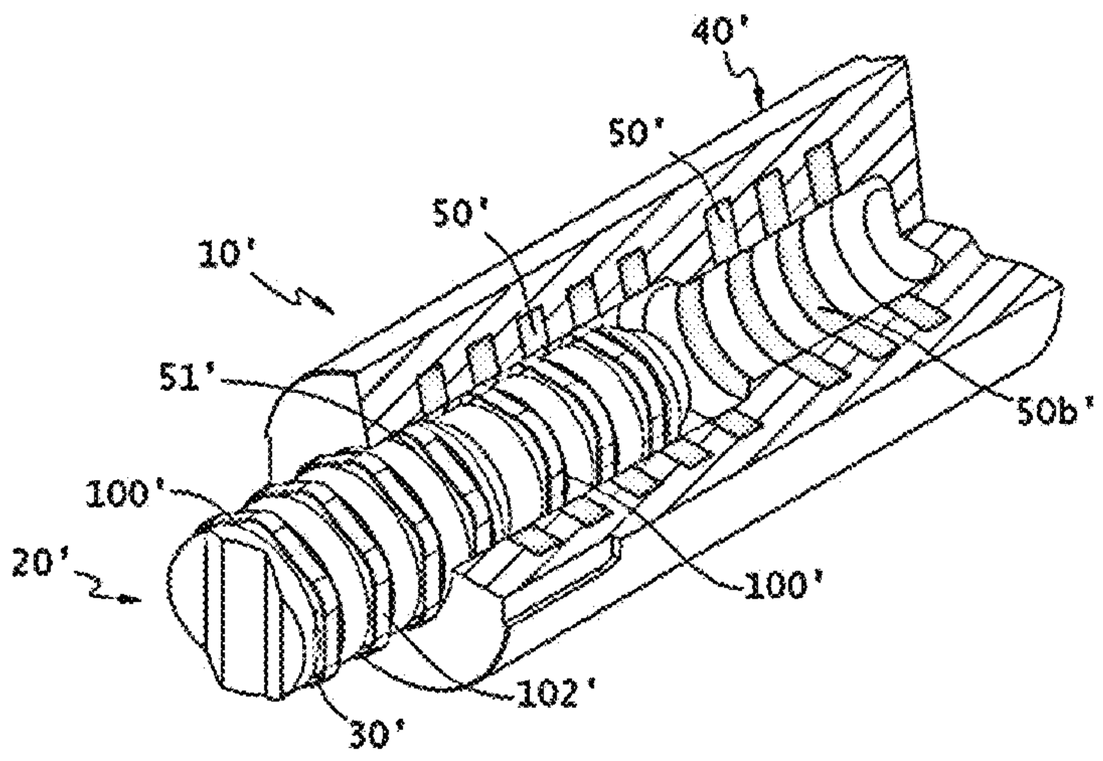
Primary Examiner — Travis S Chambers
(74) *Attorney, Agent, or Firm* — Bracewell LLP; Douglas W. Rommelmann

(57) **ABSTRACT**

An electrical connector comprising a plug arranged and designed to connect to a receptacle. The plug includes an electrically-insulating body, a conductor ring, and a conductive member connected to the plug conductor ring. The receptacle includes an electrically-insulating body, a conductor ring having an axial inner bore and an annular groove facing radially inward, a conductive member connected to the receptacle conductor ring, and an electrically-conductive contact having a generally annular profile, at least a portion of the electrically-conductive contact received in and contacting the annular groove and at least a portion of the electrically-conductive contact not received in the annular groove. Upon insertion of the plug into the receptacle and substantially radially aligning the plug and receptacle conductor rings, the electrically-conductive contact is elastically
(Continued)



deformed and provides electrical contact between the plug conductor ring and the receptacle conductor ring.

25 Claims, 14 Drawing Sheets

Related U.S. Application Data

(60) Provisional application No. 62/842,841, filed on May 3, 2019.

(51) **Int. Cl.**

H01R 13/10	(2006.01)
H01R 13/11	(2006.01)
H01R 24/58	(2011.01)
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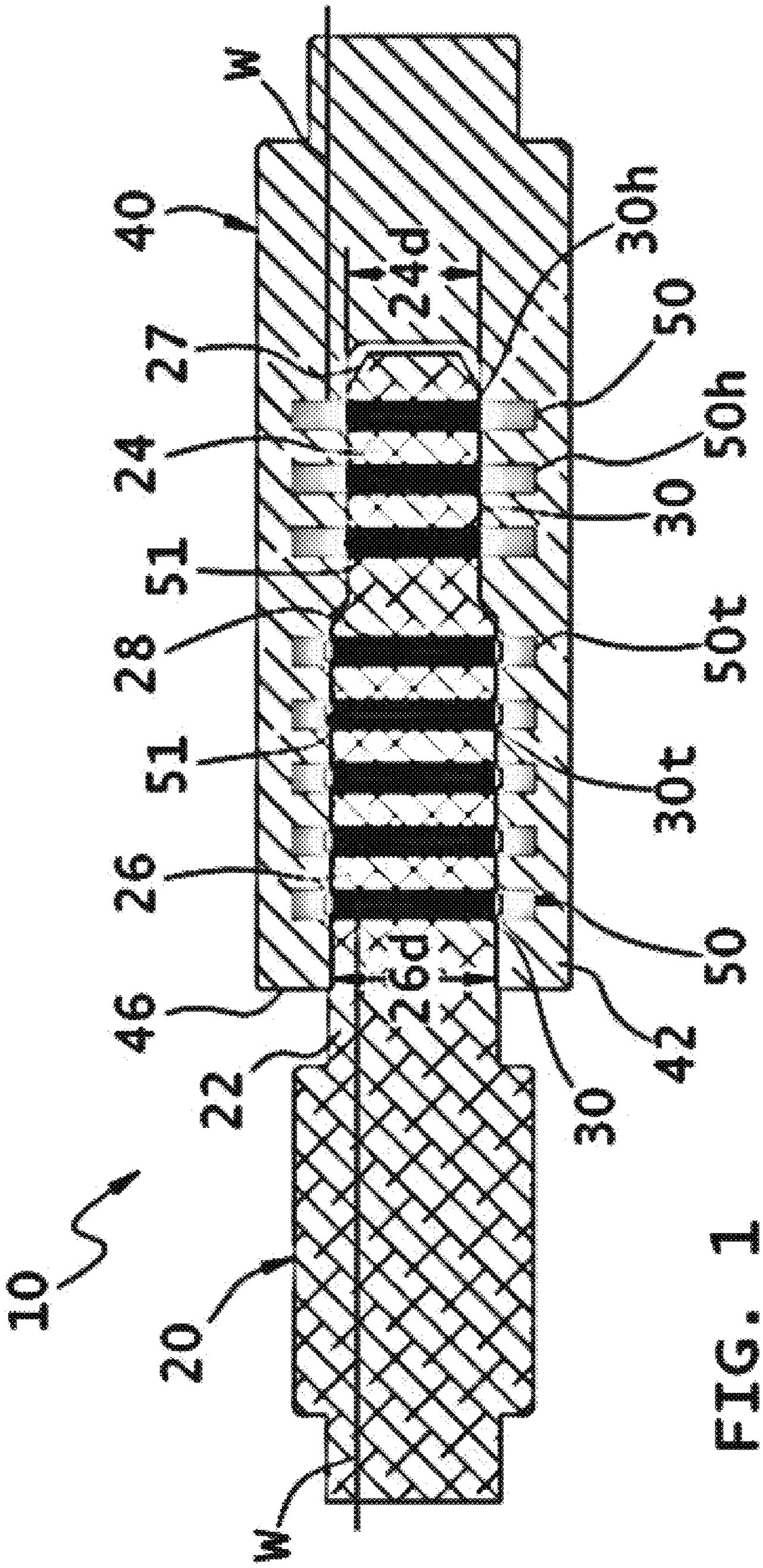

FIG. 1

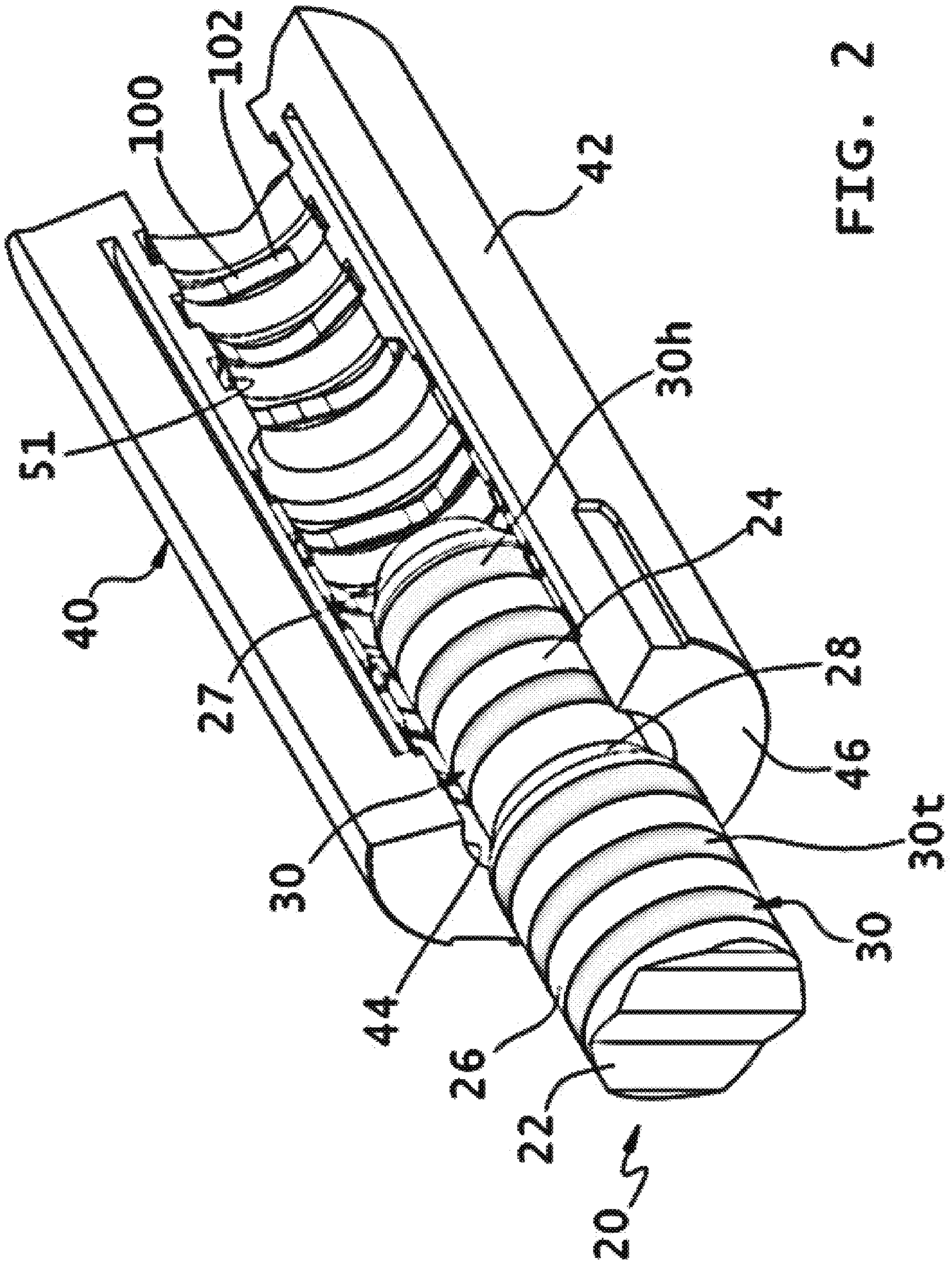

FIG. 2

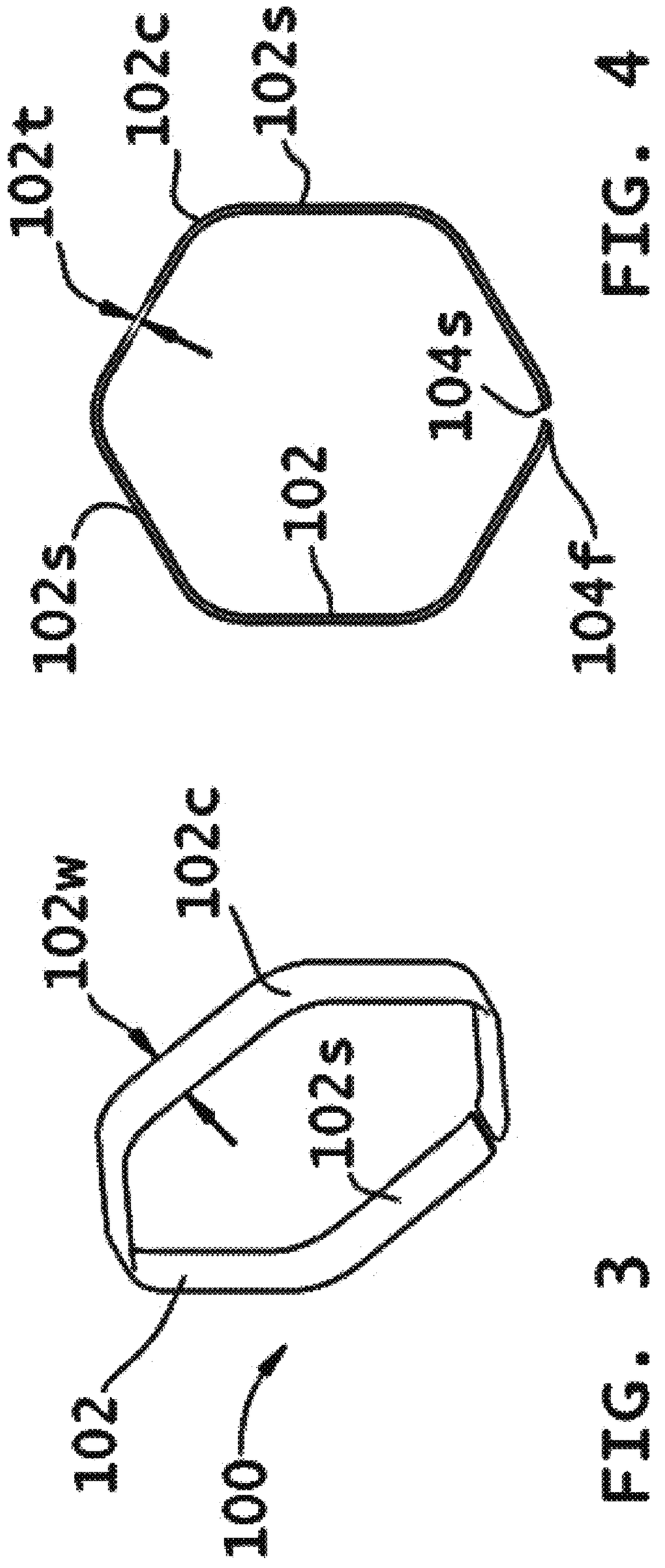

FIG. 4

FIG. 3

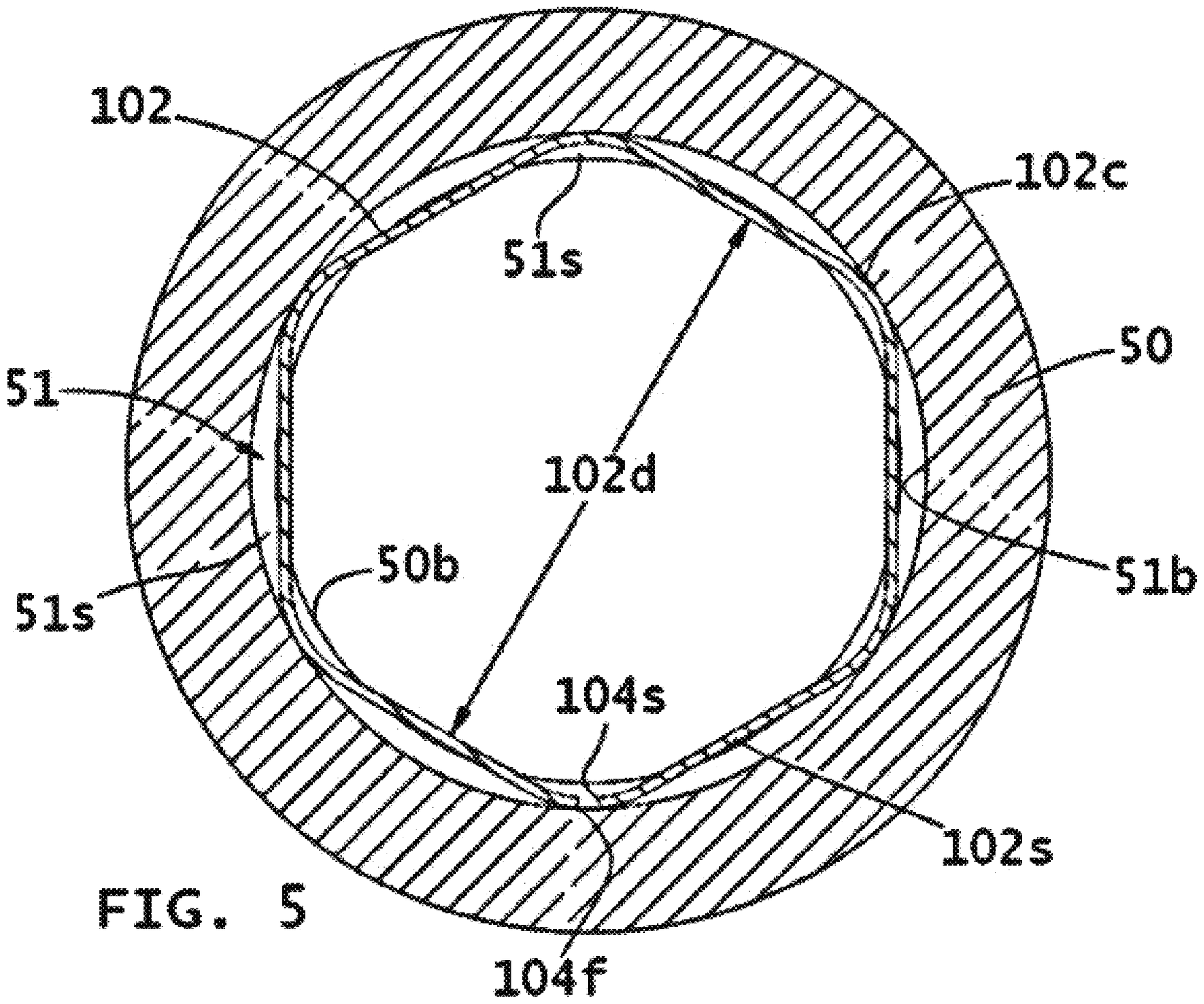

FIG. 5

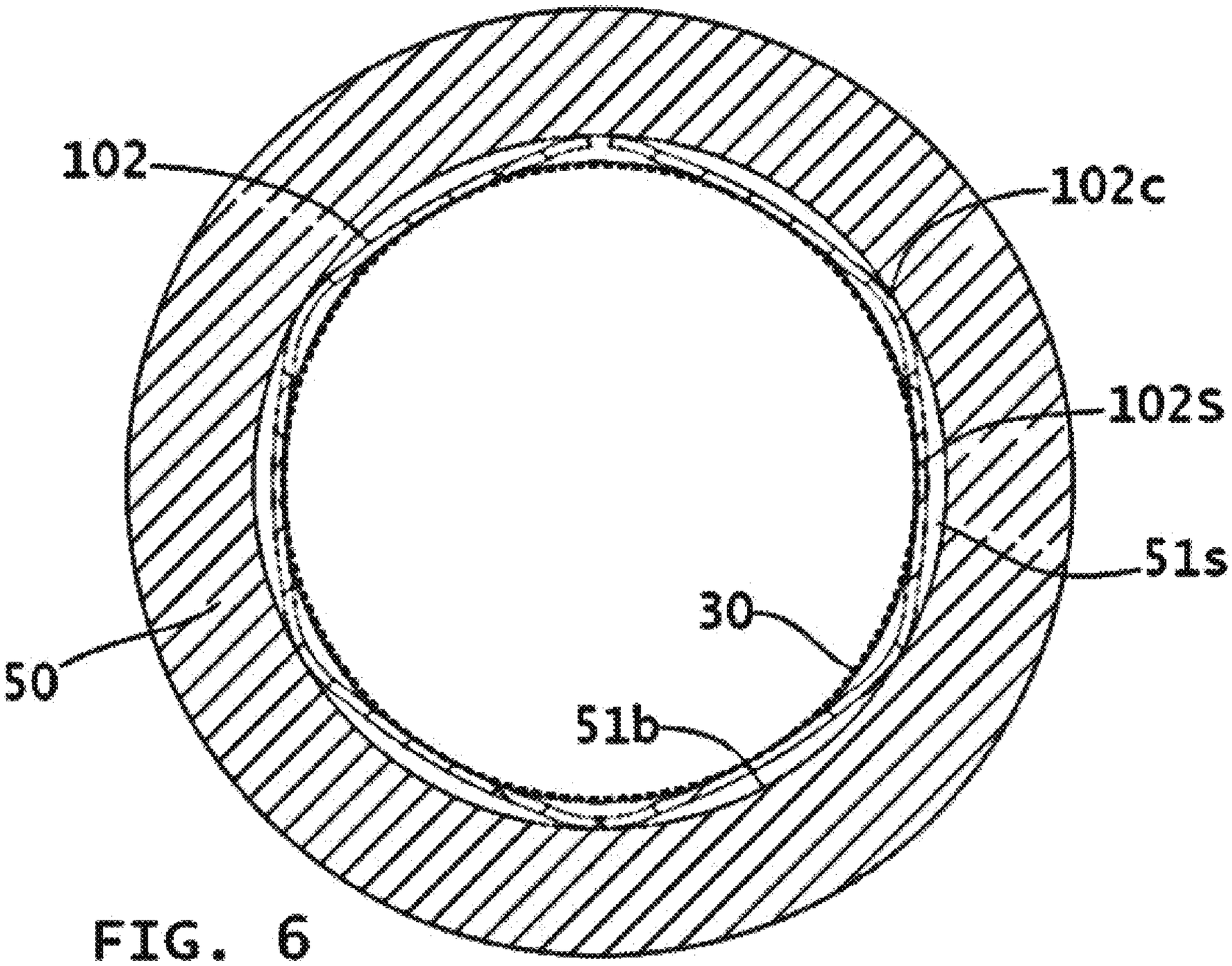

FIG. 6

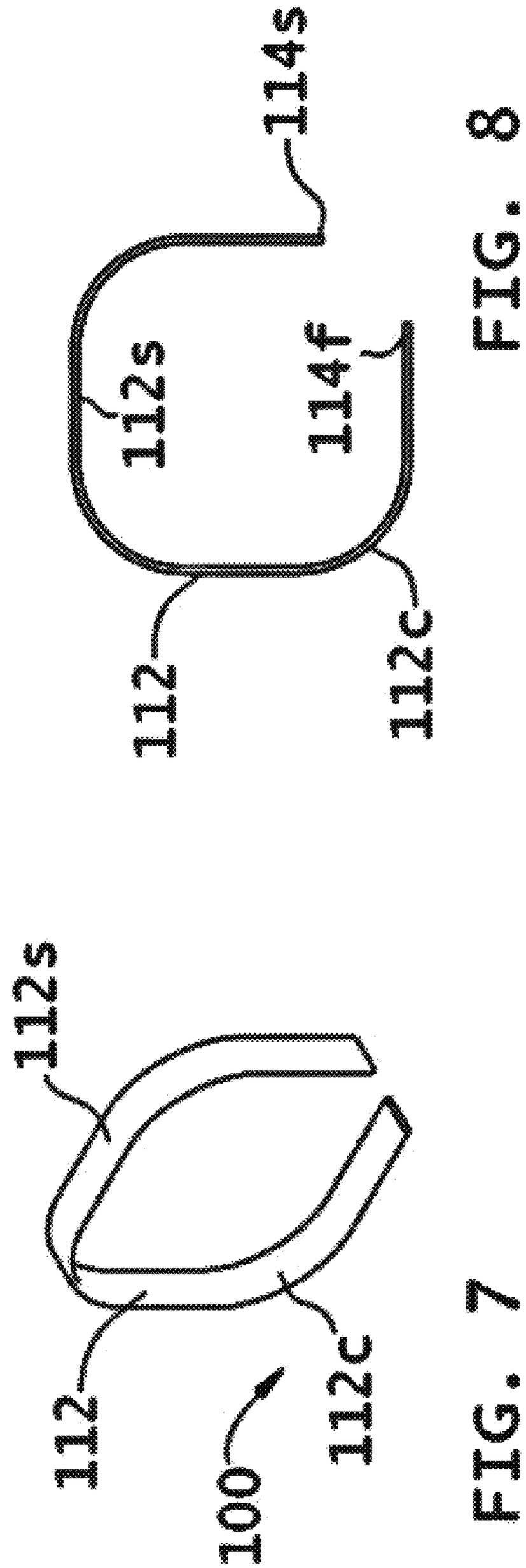

FIG. 8

FIG. 7

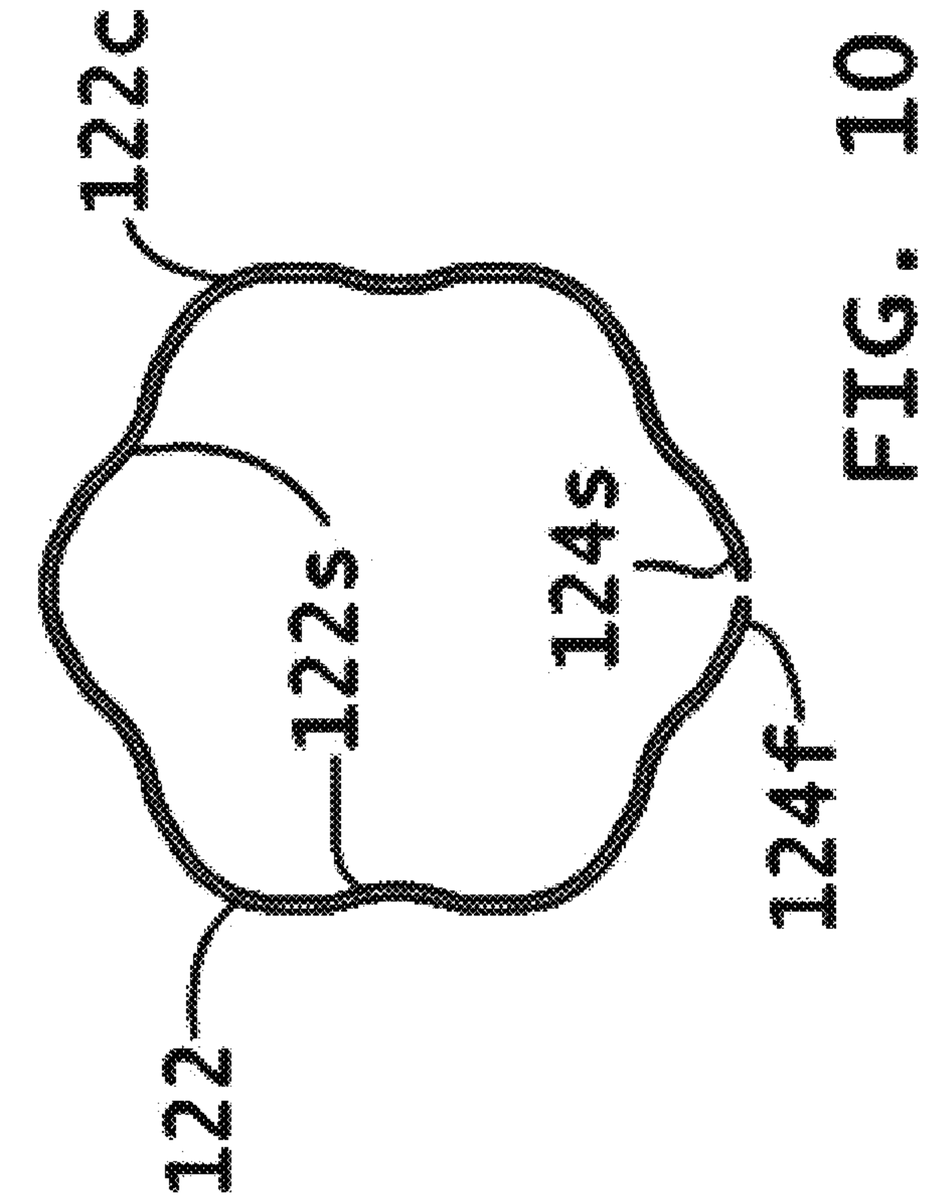

FIG. 10

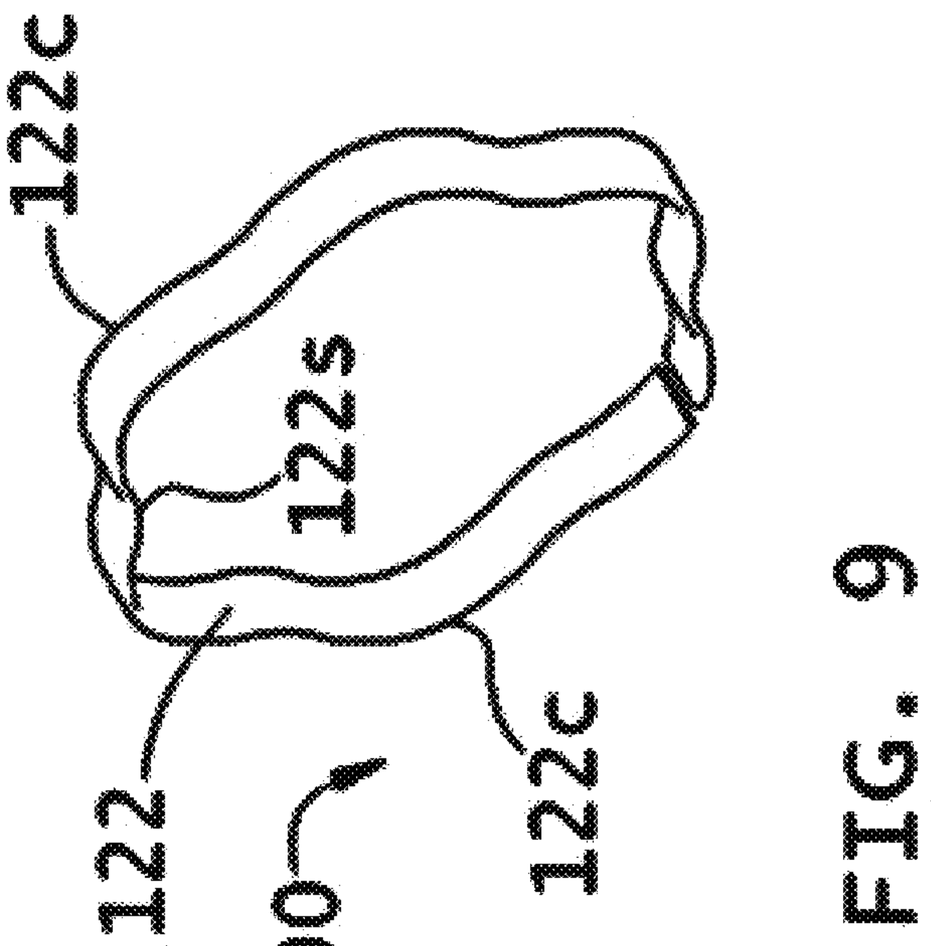

FIG. 9

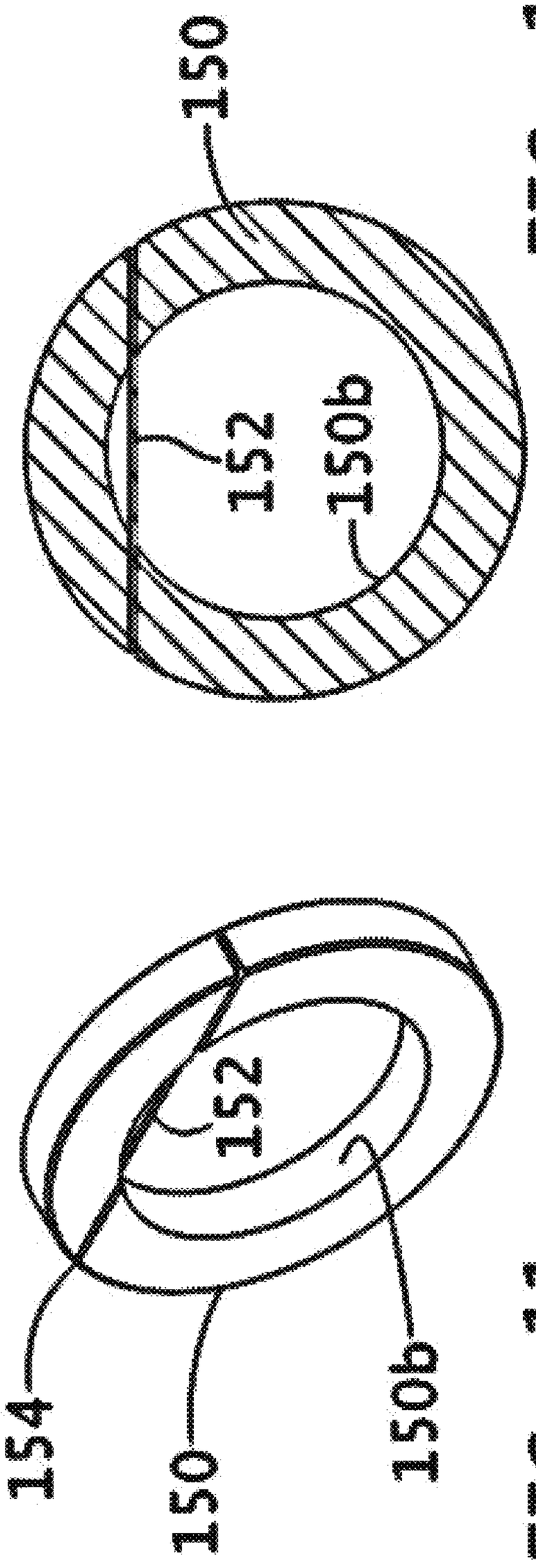

FIG. 12

FIG. 11

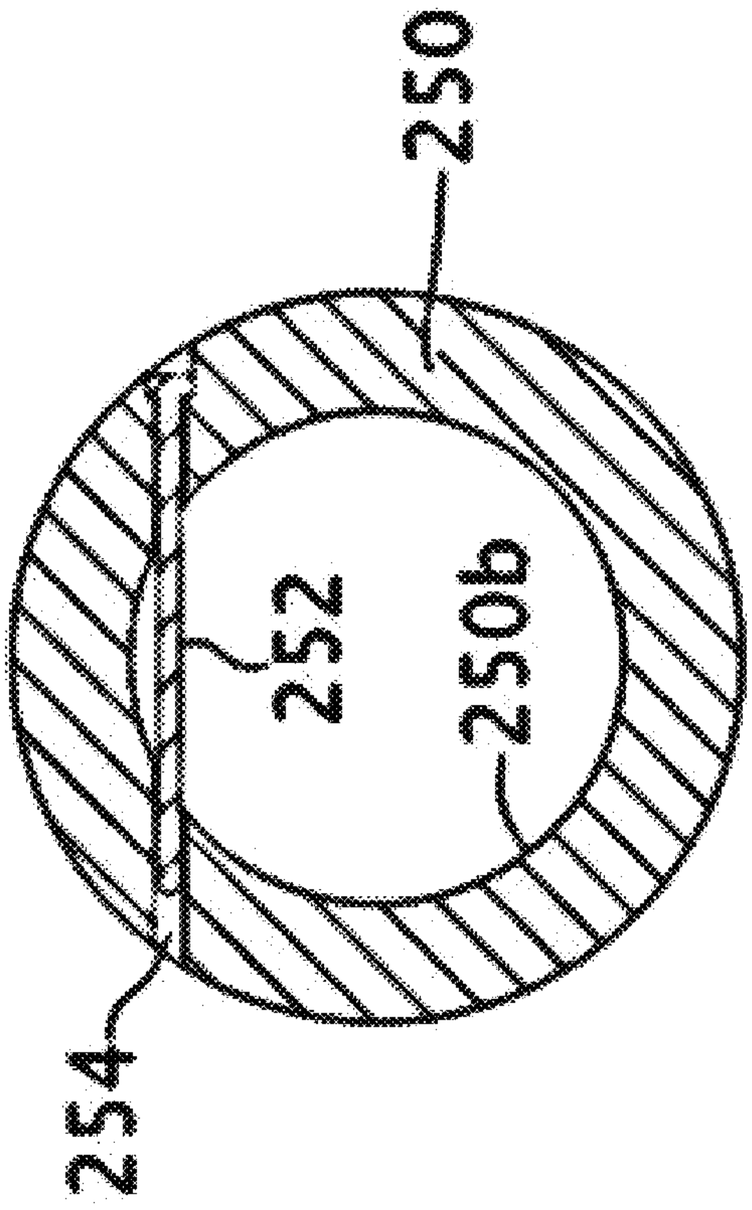

FIG. 14

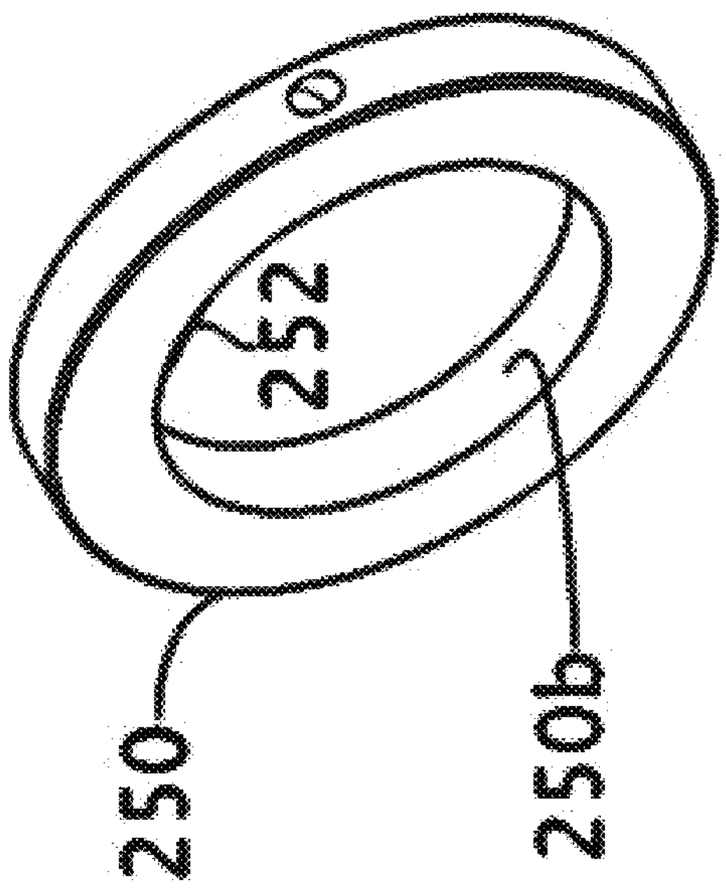

FIG. 13

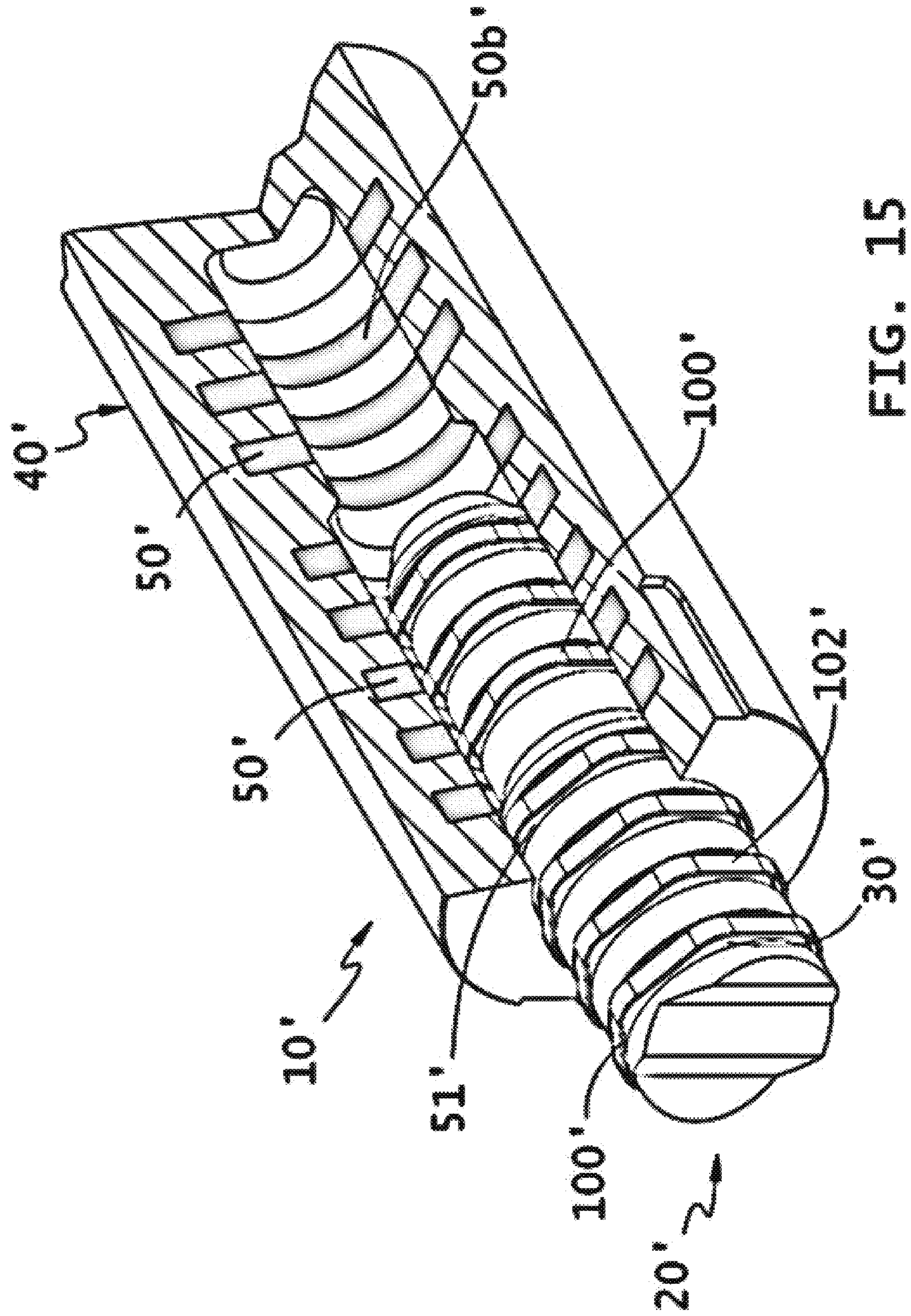

FIG. 15

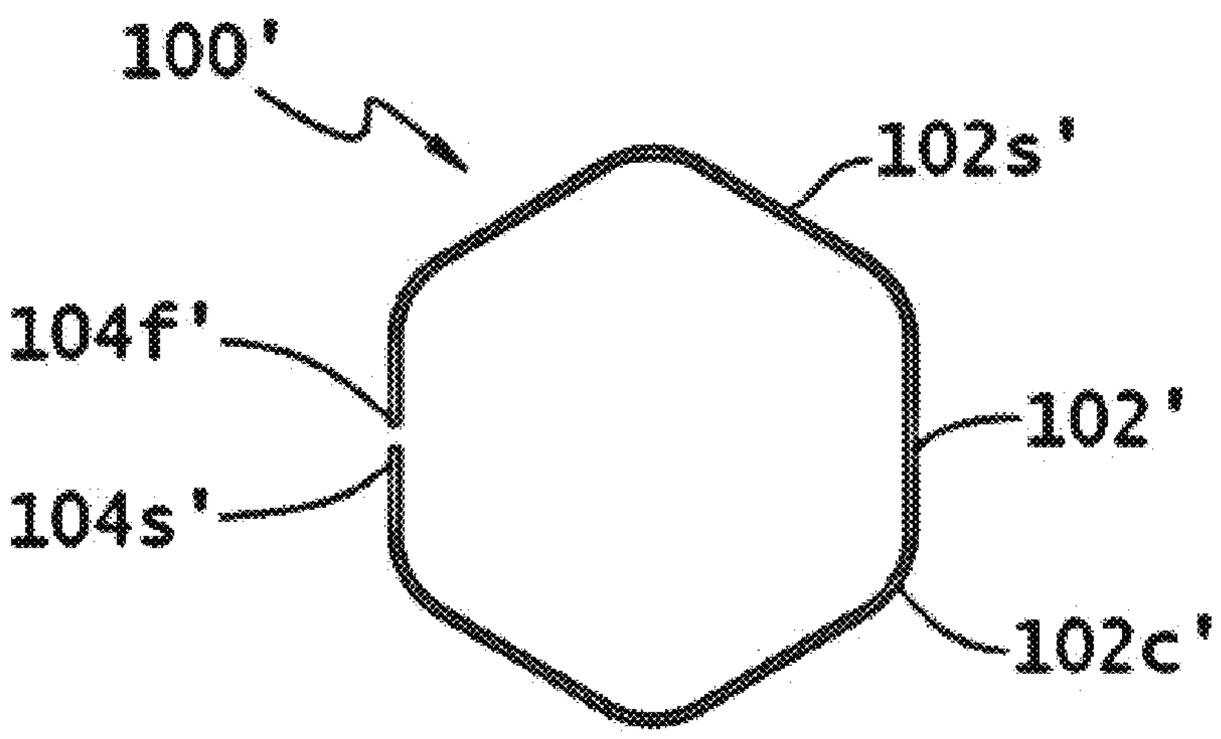

FIG. 16

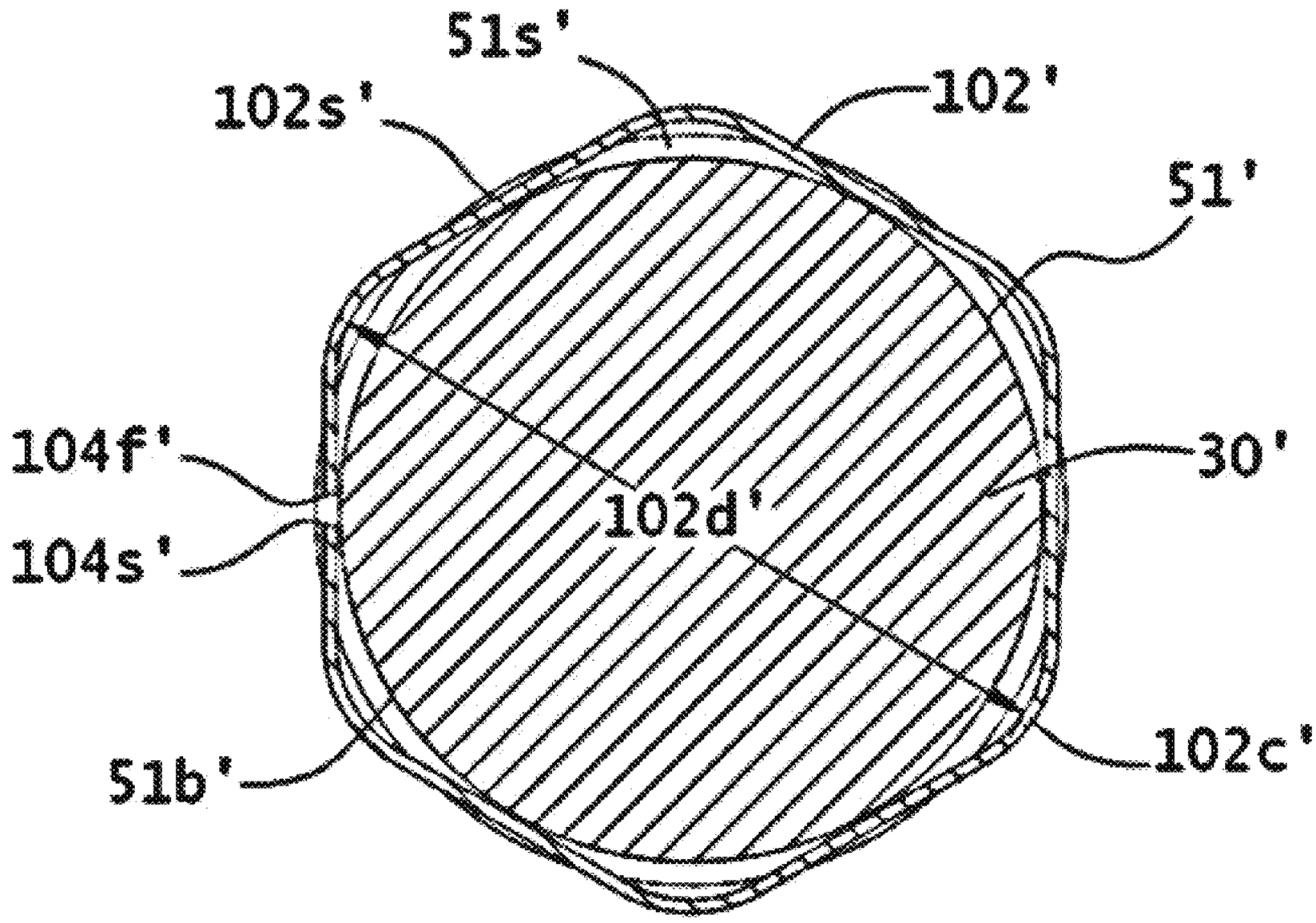

FIG. 17

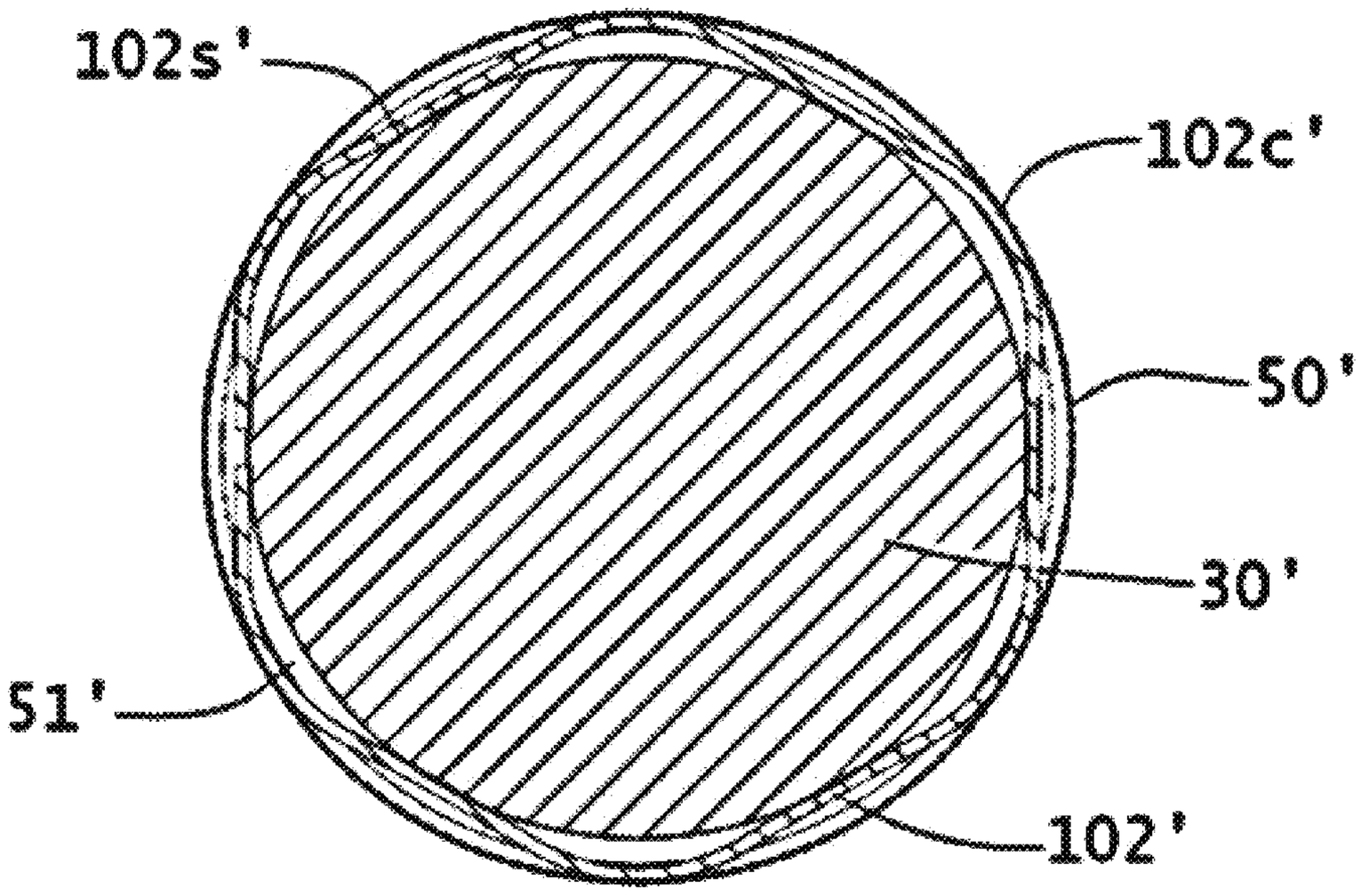

FIG. 18

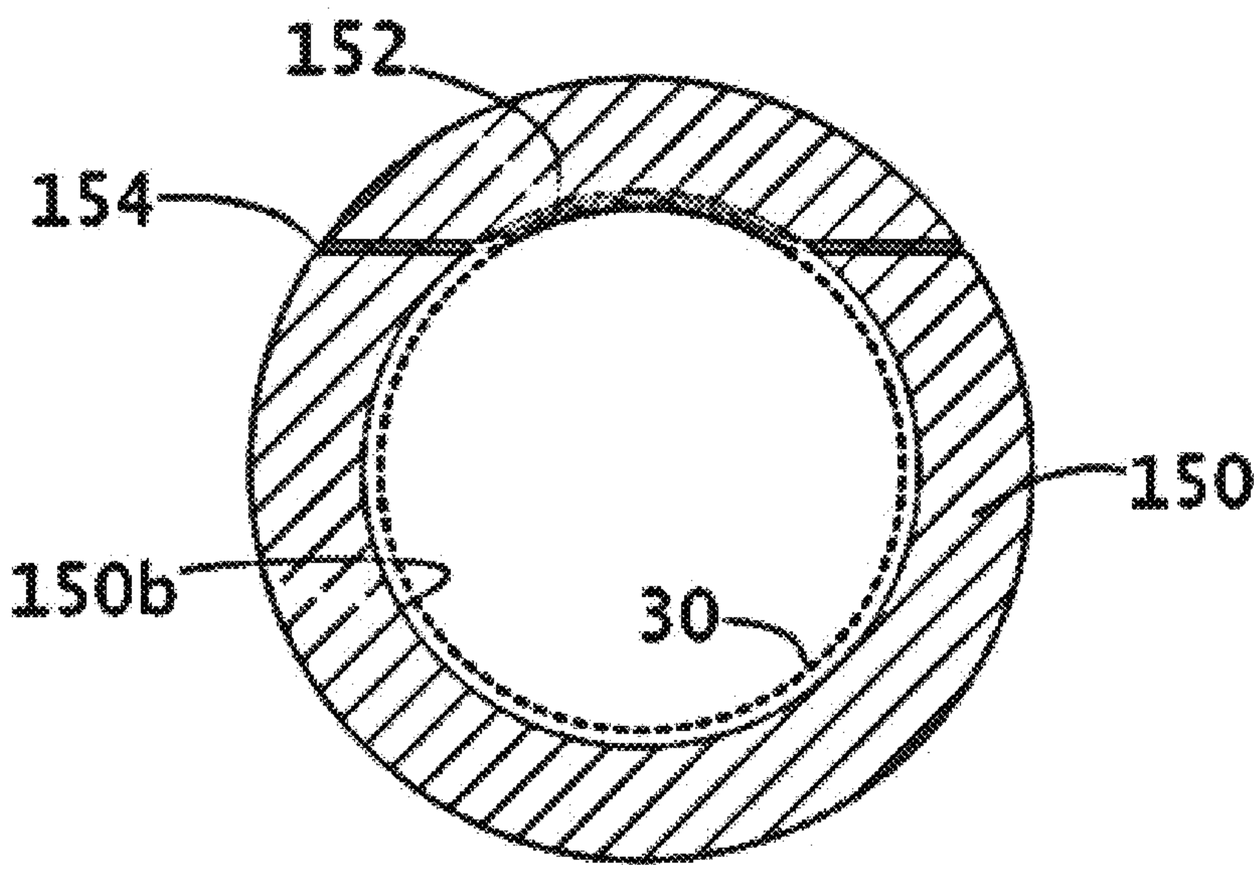

FIG. 19

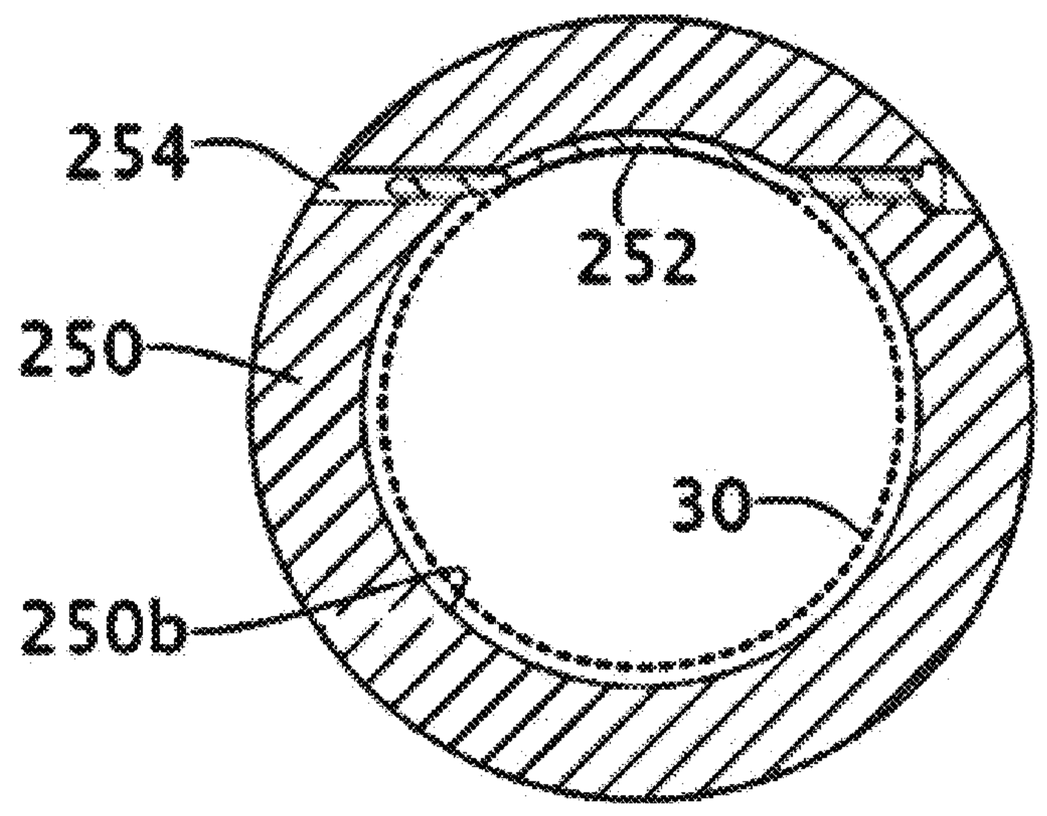

FIG. 20

MULTI-CONDUCTOR ROTARY CONNECTOR

CROSS-REFERENCE TO RELATED APPLICATIONS

This application is a continuation application of U.S. application Ser. No. 16/864,643, filed May 1, 2020, now U.S. Pat. No. 11,217,928, which claims the benefit of U.S. Provisional Application Ser. No. 62/842,841, filed May 3, 2019, entitled "Multi-Conductor Rotary Connector." Applicant incorporates by reference herein application Ser. Nos. 16/864,643 and 62/842,841 in their entirety.

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates generally to electrical, multiple conductor rotary connectors, and more specifically to the contacts for electrical, multiple conductor rotary connectors.

2. Description of the Related Art

Electrical rotary connectors typically include a male assembly and a female assembly that engage one another and permit rotation of the male and female assemblies with respect to one another. Oftentimes, the joining of the male and female assemblies will have relative rotation as a result of threaded members. Sometimes it is desirable, that upon mating of the male and female assemblies to one another, for relative rotation to exist between the two assemblies while maintaining the electrical contacts.

The male assembly is adapted to removably seat in the female assembly. The male assembly typically has at least two spaced conductor rings on an outer surface and the female assembly has a corresponding number of spaced conductor rings on an inner surface spaced so as to be juxtaposed with the male assembly conductor rings when the male assembly is seated in the female assembly.

Typically, a member often referred to as a contact or electrically-conductive contact is positioned in an annular space between the juxtaposed conductor rings to allow for connector make-up, manufacturing tolerances and to ensure electrical connectivity is maintained between each pair of juxtaposed conductor rings when the male and female assemblies are mated.

One type of contact used by Greene, Tweed & Company of Kulpsville, Pa., is a multi-leaf spring contact. The multi-leaf spring contact is installed within the female assembly. Thin metal leaves are uniformly spaced around the conductor ring in the axial direction with a "free end" of the metal leaf facing the rear of the female assembly. A rubber O-ring is positioned beneath the "free end" to energize the thin leaf springs.

Some shortcomings with the O-ring energized multi-leaf spring contact are: the thin metal leaves are fragile and break easily; the thin metal leaves are easily snagged during cleaning with rags, etc. thus causing breakage and/or permanent damage; low conductor cross-sectional area limiting electrical current capacity; the O-ring energizers are subject to compression set at elevated temperatures; does not allow for unitized plastic molding around contacts due to many leak pathways; and not axially compact.

U.S. Pat. No. 7,052,297 titled "Rotary Connector having Removable and Replaceable Contacts," assigned to Wireline

Technologies, Inc. of Houston, Tex., discloses a canted coil spring contact for rotary connectors. The objects of the invention in the '297 patent are to provide an electrically-conductive contact that is replaceable and that is easily and quickly replaced in the field without extensive disassembly of the rotary connector. Although canted coil springs are easily replaced, they are suspect/prone to having very low durability—especially in harsh operating conditions such as high temperature, high pressure environments, or when subjected to vibrational forces, or cyclical loading—experienced in many applications where rotary connectors are used. The canted coil spring often cracks during operation and is prone to getting snagged and dislodged when cleaning the connector. The canted coil spring may become dislodged during connection or disconnection of the coupler or due to allowable manufacturing tolerances of the connector which may result in slight misalignment of the mating connectors. The canted coil spring is not axially compact as it becomes ovoid when squeezed radially during mating of the rotary connector.

Another prior art rotary electrical connector includes spring-loaded pogo pin contacts. Pogo pins are subject to movement during shock and vibration thus causing potential electrical signal issues and mechanical damage. Pogo pins are prone to shearing during mating of connectors thus causing permanent damage. Other disadvantages with spring-loaded pogo pin contacts are: pogo pins are not replaceable; no unitized plastic molding around contacts is possible due to plastic invasion into back side of the pogo canister; and not radially or axially compact so connectors cannot be as compact.

It is desirable to have a rotary electrical connector that is durable, can withstand intense vibrations and is resistant to fatigue failure. It is further desirable that the connector is durable over numerous connect and disconnect cycles. It is further desirable that the rotary electrical connector is compact. It is further desirable that the rotary electrical connector can work in high temperature, high pressure (HTHP) environments, as for example in the oilfield. It is desirable that the contact has one or more of the following characteristics: high durability, high electrical current capacity, very high shock and vibration tolerance, and little likelihood of damage during maintenance and during connecting and disconnecting the rotary connector.

SUMMARY OF THE INVENTION

The preferred embodiments of the invention provide a rotary connector having a plug and a receptacle with high durability during operation, in addition to having very low likelihood of damage during maintenance. In the rare event that a contact is damaged, the contact is replaceable. The rotary connector has very high shock and vibration tolerance making it well-suited for use in extreme and difficult environments. The preferred embodiments provide a connector having high electrical current capacity. The rotary connector is radially and axially compact, thus allowing for a smaller form factor connector. At least some of the embodiments allow for unitized molded assembly.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

The aspects, features, and advantages of the embodiments of the invention mentioned above are described in more

detail by reference to the drawings, wherein like reference numerals represent like elements having the same basic function, in which:

FIG. **1** is cross-sectional view of a rotary connector according to a preferred embodiment of the present invention, showing a plug inserted in a receptacle;

FIG. **2** is a partial perspective view of the rotary connector of FIG. **1**, the perspective view having a portion of the receptacle removed and showing the plug partially within the receptacle;

FIG. **3** is a perspective view of an electrically-conductive contact according to a preferred embodiment of the invention;

FIG. **4** is a front view of the contact shown in FIG. **3**;

FIG. **5** is a cross-sectional view of the contact of FIGS. **3** and **4** received in a groove of a conductor ring in the receptacle, the contact shown in a relaxed position;

FIG. **6** is a cross-sectional view similar to FIG. **5**, showing the contact in a deformed position with the conductor ring of the plug shown in dashed lines;

FIG. **7** is a perspective view of a contact according to another embodiment of the invention;

FIG. **8** is a front view of the contact shown in FIG. **7**;

FIG. **9** is a perspective view of a contact according to another embodiment of the invention;

FIG. **10** is a front view of the contact shown in FIG. **9**;

FIG. **11** is a perspective view of an alternative embodiment of a receptacle conductor ring with a contact inserted into a slot in the conductor ring;

FIG. **12** is a front, cross-sectional view of the conductor ring and contact shown in FIG. **11**;

FIG. **13** is a perspective view of an alternative embodiment of the conductor ring with a contact inserted in a hole in the conductor ring;

FIG. **14** is a front, cross-sectional view of the conductor ring and contact shown in FIG. **13**;

FIG. **15** is a partial perspective view of an alternative embodiment of the rotary connector, the perspective view having a portion of the receptacle removed and showing the plug partially within the receptacle and with electrically-conductive contacts installed on the plug;

FIG. **16** is a front view of an embodiment of an electrically-conductive contact for installation on the plug; and

FIG. **17** is a cross-sectional view of the contact of FIG. **16** received in a groove of a conductor ring in the plug, the contact shown in a relaxed position;

FIG. **18** is a cross-sectional view similar to FIG. **17**, showing the contact in a deformed position with the conductor ring of the receptacle shown in dashed lines;

FIG. **19** is a cross-sectional view similar to FIG. **12**, showing the receptacle conductor ring with the contact in a deformed position and the plug conductor ring shown in dashed lines; and

FIG. **20** is a cross-sectional view similar to FIG. **14**, showing the receptacle conductor ring with the contact in a deformed position and the plug conductor ring shown in dashed lines.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

It should be understood at the outset that although illustrative implementations of one or more embodiments are described below, the disclosed assemblies, systems and methods may be implemented using any number of techniques, whether currently known or not yet in existence. The disclosure should in no way be limited to the illustrative implementations, drawings, and techniques described below, but may be modified within the scope of the appended claims along with their full scope of equivalents.

The following brief definition of terms shall apply throughout the application:

The phrases "in one embodiment," "according to one embodiment," and the like generally mean that the particular feature, structure, or characteristic following the phrase may be included in at least one embodiment of the present invention, and may be included in more than one embodiment of the present invention (importantly, such phrases do not necessarily refer to the same embodiment);

If the specification describes something as "exemplary" or an "example," it should be understood that refers to a non-exclusive example;

The terms "about" or "approximately" or the like, when used with a number, may mean that specific number, or alternatively, a range in proximity to the specific number, as understood by persons of skill in the field of the art;

If the specification states a component or feature "may," "can," "could," "should," "would," "preferably," "possibly," "typically," "optionally," "for example," "often," or "might" (or other such language) be included or have a characteristic, that particular component or feature is not required to be included or to have the characteristic. Such component or feature may be optionally included in some embodiment, or it may be excluded.

Embodiments of the invention will now be described with reference to the figures, in which like numerals reflect like elements throughout. The terminology used in the description presented herein is not intended to be interpreted in any restrictive or limited way, simply because it is being utilized in conjunction with the detailed description of certain specific embodiments of the invention. Furthermore, embodiments of the invention may include several novel features, no single one of which is solely responsible for its desirable attributes or which is essential to practicing the invention described herein.

Referring to FIG. **1**, a rotary connector, generally referred to as **10**, is shown having a plug **20** fully inserted within a receptacle **40**. The rotary connector **10** in FIG. **1** is an eight pin, stepped rotary connector. There are eight electrical conductor rings **30** of the plug **20** that are juxtaposed to and/or in substantially radial alignment with eight electrical conductor rings **50** of the receptacle **40** when the plug **20** is seated in the receptacle **40**. It is to be understood that each pair of opposing conductor rings **30**, **50** acts cooperatively to conduct electricity through the rotary connector **10**.

An electrical wire or conductive member W is routed from each conductor ring **30** within the plug **20** and exits the rear of the plug **20** or connects to a terminal at the rear of the plug **20**. Similarly, an electrical wire or conductive member W is routed from each conductor ring **50** within the receptacle **40** and exits the rear of the receptacle **40** or connects to a terminal at the rear of the receptacle **40**. For purposes of clarity, FIG. **1** shows only one wire W connected to one plug conductor ring **30** and one wire W connected to one receptacle conductor ring **50**. As is well understood in the art, each conductor ring **30** and **50** is connected to a separate wire or conductive member W which is accessible or exits at the rear of the plug **20** and receptacle **40**, respectively.

It is to be understood that the number of pairs of conductor rings **30**, **50** will depend on the number of electrical signals or pathways needed for the specific rotary connector **10**. Thus, while eight pairs of conductor rings are shown in FIG. **1**, this is merely for illustration and not limiting to the invention.

As stated above, the rotary connector **10** shown in FIG. **1** is a stepped rotary connector. The plug **20** has a stepped outer diameter and the receptacle **40** has a stepped inner diameter. It is to be understood that this is well known to those skilled in the art and often used when there are several pairs of conductor rings **30**, **50** in the rotary connector **10**. It is to be understood that the plug **20** and receptacle **40** of the present invention could both have a uniform diameter or both have a plurality of stepped diameters.

Referring to FIGS. **1** and **2**, the plug **20** includes an insulating body **22** having a head portion **24** and a tail portion **26**. The head portion **24** has a head diameter **24***d* and the tail portion **26** has a tail diameter **26***d*. A tapered transition **28** preferably joins the head portion **24** to the tail portion **26**. The tail diameter **26***d* is larger than the head diameter **24***d*. It is to be understood that the plug insulating body **22** may alternatively be of uniform diameter. The plug insulating body **22** is preferably made of a dielectric or non-electrically conductive material. One such suitable material is polyether ether ketone (PEEK). A forward end **27** of the plug insulating body **22** is preferably tapered or rounded to provide guidance.

With reference to FIG. **1**, the electrical conductor rings **30** of the plug **20** are preferably circular and have a smooth outer surface. FIG. **1** shows three conductor rings **30** on the head portion **24** and five on the tail portion **26**. The number of plug conductor rings **30** will depend on the number of electrical signals or pathways needed for the specific rotary connector **10**. The plug conductor rings **30** are separated from one another by a non-conducting ring, spacer or a portion of the plug insulating body **22** in the event the plug **20** is a molded assembly. The actual assembly of the plug **20** is not critical to the claimed invention. One of ordinary skill in the art is familiar with various ways of assembling the plug **20**.

The plug conductor rings **30** preferably have an outer diameter substantially equal to or slightly greater than the corresponding diameter of the adjacent portion of the plug insulating body **22** in the embodiment shown in FIGS. **1** and **2**. The plug conductor rings **30** on the head portion **24** are designated **30***h* and the plug conductor rings **30** on the tail portion **26** are designated **30***t*. The plug conductor rings **30** are made from an electrically conductive material, as for example, beryllium copper.

The receptacle **40** includes an insulating body **42** that is preferably substantially cylindrical and has a bore **44** open at a front end **46** of the receptacle **40**. The bore **44** is sized and shaped to correspond with the size and shape of the head and tail portions **24** and **26** of the plug **20**. The receptacle **40** includes a number of conductor rings **50** corresponding to the number of plug conductor rings **30**. The receptacle conductor rings **50** that are arranged and designed to align with the plug conductor rings **30***h* on the head portion **24** are designated **50***h* and those arranged and designed to align with the plug conductor rings **30***t* on the tail portion **26** are designated **50***t*. The receptacle conductor rings **50***h* preferably have an axial, circular inner bore **50***b* (FIG. **5**) with an inside diameter slightly greater than the head diameter **24***d* and the outside diameter of the head portion conductor rings **30***h*. Similarly, the receptacle conductor rings **50***t* preferably have an axial, circular inner bore with an inside diameter slightly greater than the tail diameter **26***d* and the outside diameter of the tail portion conductor rings **30***t*. The receptacle conductor rings **50** are made from an electrically conductive material, as for example, beryllium copper.

In a preferred embodiment as shown in FIGS. **1** and **2**, a radially inward-facing groove **51**, preferably annular, is made in the receptacle conductor rings **50** for at least partially receiving an electrically-conductive contact **100**. Preferably, the inward-facing groove **51** is recessed radially outward of the inner bore **50***b* of the receptacle conductor rings **50**. The contacts **100** are shown in the grooves **51** in FIG. **2**. The electrically-conductive contacts **100** are made from an electrically conductive material.

In some embodiments of the present invention, the electrically-conductive contact **100** has a generally annular profile defining an opening. FIGS. **3** and **4** show a preferred design for the electrically-conductive contact **100**. FIGS. **3** and **4** show a generally polygonal-shaped contact **102** having arcuate portions or rounded corners or vertices **102***c* and generally straight segments **102***s*. The generally polygonal-shaped contact **102** shown in FIGS. **3** and **4** includes six substantially straight segments **102***s* joined by rounded corners **102***c* defining an opening within the generally polygonal-shaped contact **102**. Preferably, the generally polygonal-shaped contact **102** is discontinuous and has first and second ends **104***f* and **104***s*, respectively. The contact **102** shown in FIGS. **3** and **4** is the contact **100** shown in the receptacle **40** in FIG. **2**, although other embodiments of the electrically-conductive contact **100** could be used. Preferably, the first and second ends **104***f*, **104***s* are located at a rounded corner **102***c* when the contact **102** is to be installed in the receptacle **40** so that the ends **104***f*, **104***s* are in the groove **51** where they are unlikely to snag on anything.

FIG. **5** shows a cross-sectional view of the six-sided polygonal-shaped contact **102** received within the groove **51** of the receptacle conductor ring **50**. The groove **51** preferably has a pair of sidewalls **51***s* (only one shown) joined by a groove base **51***b* defining a groove width and a groove depth. Preferably, the sidewalls **51***s* extend radially outward from the inner bore **50***b* to the groove base **51***b* and the axial distance between the sidewalls **51***s* defines the groove width. Preferably, the groove width is in the range of about 0.001" to 0.015" wider than the contact width **102***w*. The groove depth is defined by the radial length of the sidewall **51***s*.

The contact **102** in FIG. **5** is in a relaxed position and has a relaxed inscribed diameter **102***d*. The generally straight segments **102***s* in the relaxed position define the relaxed inscribed diameter **102***d*. For the contact **102** shown in FIG. **5**, the relaxed inscribed diameter **102***d* is the shortest distance between oppositely facing generally straight segments **102***s*. At least a portion, typically a mid-portion, of the generally straight segments **102***s* is positioned outside of the groove **51** in the relaxed position as shown in FIG. **5**. Stated another way, the relaxed inscribed diameter **102***d* is smaller than the inside diameter of the receptacle conductor ring **50**. Preferably, the relaxed inscribed diameter **102***d* is smaller than the outer diameter of the corresponding plug conductor ring **30**.

Still referring to FIG. **5**, the contact **102** is in the relaxed position when the plug **20** is uncoupled from the receptacle **40** and when the plug **20** is not juxtaposed or contacting the contact **102**. The first and second ends **104***f* and **104***s* of the generally polygonal-shaped contact **102** are adjacent the groove base **51***b* and preferably have an edge portion contacting the groove base **51***b*. Preferably, each of the rounded corners **102***c* are in contact with the groove base **51***b* when in the relaxed position.

FIG. **6** is representative of when the plug **20** and receptacle **40** are fully joined or coupled together and the contact **102** is in an elastically deformed position. The outer surface of the plug conductor ring **30** is shown in dashed lines in FIG. **6**. Since the outer diameter of the plug conductor ring **30** is preferably at least slightly larger than the relaxed

inscribed diameter **102***d* of the contact **102**, the juxtaposed plug conductor ring **30** forces the straight segments **102***s* to bend slightly outwardly such that the contact **102** is slightly more circular. As shown in FIG. **6**, the elastically deformed straight segments **102***s* provide a substantial amount of surface area contact with the outer surface of the plug conductor ring **30**. Additionally, the contact **102** concurrently retains substantial contact with the groove base **51***b*. It is also to be understood that a portion of the side surfaces of the contact **102** facing the groove sidewalls **51***s* will also likely be in contact with at least one of the sidewalls **51***s*. The contact **102** is sufficiently elastic such that electrical contact is achieved and maintained between the corresponding plug and receptacle conductor rings **30**, **50**, when the plug **20** and receptacle **40** are fully mated, yet when the plug **20** is disconnected or removed from the receptacle **40** the contact **102** remains in the groove **51** and returns to its relaxed position with an inscribed diameter **102***d* smaller than the outer diameter of the mating plug conductor ring **30**.

In the mated condition of the plug **20** and receptacle **40**, the plug conductor rings **30** are radially aligned, or substantially radially aligned, with corresponding receptacle conductor rings **50**.

It is to be understood that the size and shape of the groove **51** is dependent on the type of contact **100** used, in addition to other design factors. Referring to FIGS. **3** and **4**, the contact **102** has a width **102***w* and a thickness **102***t*. The groove width, defined by the distance between the sidewalls **51***s*, is preferably slightly wider than the contact width **102***w*. Following are some representative dimensions for the groove **51** and contact **102** merely for exemplary purposes to illustrate an embodiment. In this example, the contact **102** has a width **102***w* of 0.060" (inches) and a thickness **102***t* of 0.008" and the groove **51** has a width of 0.064" and a depth in the range of 0.016" to 0.027" depending on various factors. Preferably, the dimensions are such that the contact **102** is securely positioned within the groove **51** and remains elastic.

The preferred embodiment of the rotary connector provides the following advantages:

High durability during operation as well as very low likelihood of damage during maintenance;

Contact is replaceable in rare instance of damage;

High electrical current capacity;

Very high shock and vibration tolerance;

Radially and axially compact thus allowing for a smaller form factor connector; and

Allows for unitized molded assembly.

FIGS. **7-14** illustrate other embodiments of electrically-conductive contacts **100**. It is to be understood that the following embodiments of electrically-conductive contacts **100** include all or some of the above advantages.

The contact **100** shown in FIGS. **7** and **8** is another generally polygonal-shaped contact, generally referred to as **112**, having rounded corners or vertices **112***c*. The generally polygonal-shaped contact **112** shown in FIGS. **7** and **8** includes rounded corners **112***c* separated by four generally straight segments **112***s*. Preferably, the generally polygonal-shaped contact **112** is discontinuous and has first and second ends **114***f* and **114***s*, respectively. Preferably, the first and second ends **114***f* and **114***s* are located such that they would remain within an inwardly facing groove **51** and contact the groove base **51***b*.

FIGS. **9** and **10** show a generally marcel-shaped contact **122** having a plurality of rounded external corners or vertices **122***c*. The generally marcel-shaped contact **122** includes a plurality of rounded external corners **122***c* separated by generally wavy segments **122***s*. Preferably, the generally marcel-shaped contact **122** is discontinuous and has first and second ends **124***f* and **124***s*, respectively. Preferably, the first and second ends **124***f* and **124***s* are located such that they would remain within an inwardly-facing groove **51** and contact the groove base **51***b*.

FIGS. **11** and **12** show an alternative receptacle conductor ring **150** having an axial inner bore **150***b*. The axial inner bore **150***b* may be a continuous axial bore, without the need to have an inwardly-facing groove. A slot **154** extends transversely through the conductor ring **150** and intersects the inner bore **150***b* at two locations. An electrically-conductive contact **152** in the form of a flexible beam is inserted into the slot and within a portion of the inner bore **150***b* as shown in FIG. **12**. The contact **152** has a relaxed position in which the contact **152** is a substantially straight member passing within the inner bore **150***b* of the receptacle conductor ring **150** as shown in FIGS. **11** and **12**.

FIG. **19** is representative of when the plug **20** and receptacle **40** are fully joined or coupled together and the contact **152** is in an elastically deformed position. The outer surface of the plug conductor ring **30** is shown in dashed lines. The outer diameter of the plug conductor ring **30** is sized so that upon mating of the plug with the receptacle, the mating plug conductor ring **30** contacts and elastically deforms the contact **152** within the inner bore **150***b*. The contact **152** is sufficiently elastic that electrical contact is achieved when deformed by plug connector ring **30**, yet when disconnected from the plug the contact **152** returns to its relaxed straight condition. The contact **152** may have a polygonal or rounded cross-section. In this alternative, the contact **152** is replaceable if the receptacle **40** is assembled, for example, by stacking insulator rings and conductor rings.

FIGS. **13** and **14** show another alternative receptacle conductor ring **250** similar to the one shown in FIGS. **11** and **12**. FIGS. **13** and **14** show an alternative receptacle conductor ring **250** having an axial inner bore **250***b*. The axial inner bore **250***b* may be a continuous axial bore, without the need to have an inwardly-facing groove. A transverse bore **254** extends through the conductor ring **250** and intersects the axial inner bore **250***b* at two locations. An electrically-conductive contact **252** is inserted into the transverse bore **254** in the conductor ring **250** and within a portion of the axial inner bore **250***b* as shown in FIG. **14**. The contact **252** has a relaxed position in which the contact **252** is a substantially straight member passing within the axial inner bore **250***b* of the receptacle conductor ring **250** as shown in FIG. **14**.

FIG. **20** is representative of when the plug **20** and receptacle **40** are fully joined or coupled together and the contact **252** is in an elastically deformed position. The outer surface of the plug conductor ring **30** is shown in dashed lines. The outer diameter of the plug conductor ring **30** is sized so that upon mating of the plug **20** with the receptacle **40**, the mating plug conductor ring **30** contacts and elastically deforms the contact **252** within the inner bore **250***b*. The contact **252** is sufficiently elastic that electrical contact is achieved when deformed by plug connector ring **30**, yet when disconnected from the plug the contact **252** returns to its relaxed straight condition. Preferably, the contact **252** has a circular cross-section. If the contact **252** is press-fitted in the conductor ring **250**, this embodiment may be used in a molded assembly. If the contact **252** is not press-fitted and the receptacle can be disassembled, the contact **252** may be replaceable.

FIG. **15** shows an alternative embodiment of the rotary connector, generally designated **10'**, which is similar in

many respects with the rotary connector **10** shown in FIGS. **1** and **2**. The primary difference is that the rotary connector **10'** has the electrically-conductive contacts **100'** installed on the plug conductor rings **30'**, preferably in outwardly-facing grooves **51'** and the receptacle conductor rings **50'** have a smooth inner bore **50***b*'. The contact **102'** shown is similar in shape to the contact **102** of FIGS. **3** and **4**. The contact **102'** is discontinuous and preferably has first and second ends **104***f*' and **104***s*' at a mid-portion of a generally straight segment **102***s*' as shown in FIG. **16**.

FIG. **17** shows a cross-sectional view of the six-sided polygonal-shaped contact **102'** received within the groove **51'** of the plug conductor ring **30'**. The groove **51'** preferably has a pair of sidewalls **51***s*' (only one shown) joined by a groove base **51***b*' defining a groove width and a groove depth. The contact **102'** is in a relaxed position and has a relaxed inscribed diameter **102***d*'. The rounded corners **102***c*' in the relaxed position define the relaxed inscribed diameter **102***d*'. For the contact **102'** shown in FIG. **17**, the relaxed inscribed diameter **102***d*' is the longest distance between oppositely facing rounded corners **102***c*'. At least a portion, typically a mid-portion, of the rounded corners **102***c*' is positioned outside of the groove **51'** in the relaxed position as shown in FIG. **17**. Preferably, the relaxed inscribed diameter **102***d*' is larger than the inside diameter of the receptacle conductor ring **50'**. Preferably, the relaxed inscribed diameter **102***d*' is larger than the outside diameter of the corresponding plug conductor ring **30'**.

Still referring to FIG. **17**, the contact **102'** is in the relaxed position when the plug **20'** is uncoupled from the receptacle **40'** and when the receptacle **40'** is not juxtaposed or contacting the contact **102'**. The first and second ends **104***f*' and **104***s*' of the generally polygonal-shaped contact **102'** are preferably adjacent the groove base **51***b*' and preferably have an edge portion contacting the groove base **51***b*'. Preferably, a portion of each of the generally straight segments **102***s*' is in contact with the groove base **51***b*' when in the relaxed position.

FIG. **18** is representative of when the plug **20'** and receptacle **40'** are fully joined or coupled together and the contact **102'** is in an elastically deformed position. The inner surface of the receptacle conductor ring **50'** is shown in dashed lines. Since the inner diameter of the receptacle conductor ring **50'** is preferably at least slightly smaller than the relaxed inscribed diameter **102***d*' of the contact **102'**, the juxtaposed receptacle conductor ring **50'** forces the contact **102'** to become slightly more circular. As shown in FIG. **18**, the elastically deformed contact **102'** provides a substantial amount of surface area contact with the inner surface of the receptacle conductor ring **50'** while concurrently retaining substantial contact with the groove base **51***b*'. It is also to be understood that a portion of the side surfaces of the contact **102'** facing the groove sidewalls **51***s*' will also likely be in contact with at least one of the sidewalls **51***s*'. The contact **102'** is sufficiently elastic such that electrical contact is achieved and maintained between the corresponding plug and receptacle conductor rings **30'**, **50'**, when the plug **20'** and receptacle **40'** are fully mated, yet when the plug **20'** is disconnected or removed from the receptacle **40'** the contact **102'** remains in the groove **51'** and returns to its relaxed position with an inscribed diameter **102***d*' larger than the inner diameter of the mating receptacle conductor ring **50'**.

It is to be understood that the groove in the conductor ring in the above described embodiments will vary based on the size, shape and type of contact. The groove is designed to create the required force for each size of contact.

It is to be understood that the cross-section shapes of the contacts in the figures are not limited to the shape illustrated (i.e., rectangular) but may comprise other shapes including, but not limited to, round.

It is to be understood that insulators between adjacent contacts can be discrete pieces or a unitized molded system. Additionally, the system allows for optional hermetic sealing of electrical connector within mating housings.

An analysis of the force required for the contact **102** shown in FIGS. **3** and **4** to yield in bending where the width **102***w* is 0.06", thickness **102***t* is 0.008" and length is 0.17" results in a force of 1.58 Newtons or 0.355 lbs. Comparable analysis for the multi-leaf spring and the canted coil spring designs described in the Background of the Invention result in yielding with forces significantly lower than for the preferred embodiment as shown below:

Design	Force (Newtons)	Force (Pounds)
FIGS. 3-4 Embodiment	1.58	0.355
Multi-Leaf Spring	0.075	0.017
Canted Coil Spring	0.175	0.039

The foregoing disclosure and description of the invention are illustrative and explanatory thereof, and various changes in the size, shape and materials, as well as in the details of the illustrated construction, may be made without departing from the spirit of the invention. The present embodiment is, therefore, to be considered as merely illustrative and not restrictive, the scope of the invention being indicated by the claims rather than the foregoing description, and all changes which come within the meaning and range of equivalence of the claims are therefore intended to be embraced therein.

While the invention has been described in detail above with reference to specific embodiments, it will be understood that modifications and alterations in the embodiments disclosed may be made by those practiced in the art without departing from the spirit and scope of the invention. All such modifications and alterations are intended to be covered. In addition, all publications cited herein are indicative of the level of skill in the art and are hereby incorporated by reference in their entirety as if each had been individually incorporated by reference and fully set forth.

We claim:

1. An electrical connector (**10'**) comprising a plug (**20'**) arranged and designed to connect to a receptacle (**40'**);

a) the receptacle (**40'**) comprising:

i) an electrically-insulating receptacle body (**42**);

ii) a receptacle conductor ring (**50'**) having an axial inner bore (**50***b*') defining an inside diameter;

iii) a receptacle electrically-conductive member (W) connected to the receptacle conductor ring (**50'**) and exiting an end of the receptacle body (**42**); and

b) the plug (**20'**) comprising:

i) an electrically-insulating plug body (**22**);

ii) a plug conductor ring (**30'**) having an outer diameter; and

iii) a plug electrically-conductive member (W) connected to the plug conductor ring (**30'**), the plug electrically-conductive member (W) within the plug body (**22**) and exiting an end of the plug body (**22**); and

iv) an electrically-conductive contact (**100'**) contacting the plug conductor ring (**30'**), the electrically-conductive contact (**100'**) having a generally annular, polygonal-shaped axial profile comprising a plurality

of substantially straight segments (**102***s*') joined by a plurality of rounded corners (**102***c*') defining an axial opening, the electrically-conductive contact (**100**') having a relaxed position and an elastically-deformed position,

in the relaxed position, the electrically-conductive contact (**100**') has a relaxed inscribed diameter (**102***d*') that is larger than the inside diameter of the receptacle conductor ring (**50**'),

in the elastically-deformed position, the electrically-conductive contact (**100**') is elastically deformed within the axial inner bore (**50***b*') of the receptacle conductor ring (**50**') by the receptacle conductor ring (**50**'), the receptacle conductor ring (**50**') contacting the electrically-conductive contact (**100**') and electrical contact is achieved between the receptacle conductor ring (**50**') and the plug conductor ring (**30**'), and

upon removal of the receptacle conductor ring (**50**') from contact with the electrically-conductive contact (**100**'), the electrically-conductive contact (**100**') returns to the relaxed position.

2. The electrical connector (**10**') of claim **1**, wherein the plug conductor ring (**30**') is one of a plurality of plug conductor rings (**30**'), the receptacle conductor ring (**50**') is one of a plurality of receptacle conductor rings (**50**'), and the electrically-conductive contact (**100**') is one of a plurality of electrically-conductive contacts (**100**'), wherein the number of plug conductor rings (**30**'), the number of receptacle conductor rings (**50**') and the number of electrically-conductive contacts (**100**') is the same.

3. The electrical connector (**10**') of claim **1**, wherein upon insertion of the plug (**20**') into the receptacle (**40**') and substantially radially aligning the plug and receptacle conductor rings (**30**' and **50**'), the plurality of substantially straight segments (**102***s*') provide electrical contact with the plug conductor ring (**30**') and the plurality of rounded corners (**102***c*') provide electrical contact with the receptacle conductor ring (**50**').

4. The electrical connector (**10**') of claim **1**, wherein the plug conductor ring (**30**') has an annular groove (**51**') facing radially outward, and at least a portion of the electrically-conductive contact (**100**') is in the annular groove (**51**').

5. The electrical connector (**10**') of claim **4**, wherein at least a portion of the electrically-conductive contact (**100**') is not in the annular groove (**51**').

6. The electrical connector (**10**') of claim **4**, wherein at least a portion of the plurality of rounded corners (**102***c*') is not in the annular groove (**51**').

7. The electrical connector (**10**') of claim **4**, wherein at least a portion of each of the plurality of rounded corners (**102***c*') is not in the annular groove (**51**').

8. The electrical connector (**10**') of claim **4**, wherein at least a portion of the plurality of substantially straight segments (**102***s*') is in the annular groove (**51**').

9. The electrical connector (**10**') of claim **4**, wherein at least a portion of each of the plurality substantially straight segments (**102***s*') is in the annular groove (**51**').

10. The electrical connector (**10**') of claim **4**, wherein the annular groove (**51**') comprises a pair of sidewalls (**51***s*') extending radially inward to a groove base (**51***b*'), and at least a portion of each of the plurality of substantially straight segments (**102***s*') contacts the groove base (**51***b*').

11. The electrical connector (**10**') of claim **4**, wherein the annular groove (**51**') comprises a pair of sidewalls (**51***s*') extending radially inward to a groove base (**51***b*'), and an axial distance between the pair of sidewalls (**51***s*') defines a groove width, and the electrically-conductive contact (**100**') has a contact width (**102***w*),

wherein the groove width is in the range of about 0.001" to 0.015" wider than the contact width (**102***w*).

12. The electrical connector (**10**') of claim **4**, wherein the electrically-conductive contact (**100**') is discontinuous and has first and second ends (**104***f*, **104***s*') received in the annular groove (**51**').

13. The electrical connector (**10**') of claim **12**, wherein the first and second ends (**104***f*, **104***s*') are at a mid-portion of one substantially straight segment (**102***s*').

14. The electrical connector (**10**') of claim **4**, wherein the annular groove (**51**') comprises a pair of sidewalls (**51***s*') extending radially inward to a groove base (**51***b*'), and at least a portion of the plurality of substantially straight segments (**102***s*') contact the groove base (**51***b*').

15. The electrical connector (**10**') of claim **14**, wherein a groove depth is defined by a radial length of one of the sidewalls (**51***s*'), and the plurality of substantially straight segments (**102***s*') and the plurality of rounded corners (**102***c*') have a contact thickness (**102***t*) that is less than the groove depth.

16. An electrical connector (**10**') comprising a plug (**20**') arranged and designed to connect to a receptacle (**40**');

a) the receptacle (**40**') comprising:

i) an electrically-insulating receptacle body (**42**);

ii) a receptacle conductor ring (**50**') having an axial inner bore (**50***b*'); and

iii) a receptacle electrically-conductive member (W) connected to the receptacle conductor ring (**50**') and exiting an end of the receptacle body (**42**); and

b) the plug (**20**') comprising:

i) an electrically-insulating plug body (**22**);

ii) a plug conductor ring (**30**') having an annular groove (**51**') facing radially outward, the annular groove (**51**') having an axial groove width;

iii) a plug electrically-conductive member (W) connected to the plug conductor ring (**30**'), the plug electrically-conductive member (W) within the plug body (**22**) and exiting an end of the plug body (**22**); and

iv) an electrically-conductive contact (**100**') being discontinuous annularly defining first and second ends (**104***f*, **104***s*') and having a generally annular profile defining an axial opening, the electrically-conductive contact (**100**') having a contact width (**102***w*) in an axial direction being less than the axial groove width, at least a portion of the electrically-conductive contact (**100**') received in and contacting the annular groove (**51**') and at least a portion of the electrically-conductive contact (**100**') not received in the annular groove (**51**'),

wherein upon insertion of the plug (**20**') into the receptacle (**40**') and substantially radially aligning the plug and receptacle conductor rings (**30**' and **50**'), the electrically-conductive contact (**100**') is elastically deformed and provides electrical contact between the plug conductor ring (**30**') and the receptacle conductor ring (**50**').

17. The electrical connector (**10**') of claim **16**, wherein the annular groove (**51**') comprises a pair of sidewalls (**51***s*') extending radially inward to a groove base (**51***b*'), and an axial distance between the pair of sidewalls (**51***s*') defines the axial groove width, and the electrically-conductive contact (**100**') has a contact width (**102***w*),

wherein the axial groove width is in the range of 0.001" to 0.015" wider than the contact width (**102***w*).

18. The electrical connector (**10'**) of claim **16**, wherein the electrically-conductive contact (**100'**) comprises a plurality of substantially straight segments (**102***s'*) joined by a plurality of corners (**102***c'*), and the generally annular profile and the defined axial opening are generally polygonal-shaped.

19. The electrical connector (**10'**) of claim **18**, wherein at least a portion of the plurality of corners (**102***c'*) is not in the groove (**51'**).

20. The electrical connector (**10'**) of claim **18**, wherein upon insertion of the plug (**20'**) into the receptacle (**40'**) and substantially radially aligning the plug and receptacle conductor rings (**30'** and **50'**), the electrically-conductive contact (**100'**) elastically deforms and the plurality of substantially straight segments (**102***s'*) provide electrical contact with the plug conductor ring (**30'**) and the plurality of corners (**102***c'*) provide electrical contact with the receptacle conductor ring (**50'**).

21. The electrical connector (**10'**) of claim **18**, wherein the annular groove (**51'**) comprises a pair of sidewalls (**51***s'*) extending radially inward to a groove base (**51***b'*),

wherein the axial groove width is defined by an axial distance between the pair of sidewalls (**51***s'*) and a groove depth is defined by a radial length of one of the sidewalls (**51***s'*), and

the plurality of substantially straight segments (**102***s'*) and the plurality of corners (**102***c'*) have a contact thickness (**102***t*) that is less than the groove depth.

22. The electrical connector (**10'**) of claim **16**, wherein the first and second ends (**104***f*, **104***s'*) are received in the annular groove (**51'**).

23. The electrical connector (**10'**) of claim **22**, wherein the electrically-conductive contact (**100'**) comprises a plurality of wavy segments (**122***s*) joined by a plurality of rounded external corners (**102***c*).

24. An electrical connector (**10'**) comprising a plug (**20'**) arranged and designed to connect to a receptacle (**40'**);

a) the receptacle (**40'**) comprising:

i) an electrically-insulating receptacle body (**42**);

ii) a receptacle conductor ring (**50'**) having an axial inner bore (**50***b'*); and

iii) a receptacle electrically-conductive member (W) connected to the receptacle conductor ring (**50'**) and exiting an end of the receptacle body (**42**);

b) the plug (**20'**) comprising:

i) an electrically-insulating plug body (**22**);

ii) a plug conductor ring (**30'**) having an outer diameter and an annular groove (**51'**) facing radially outward;

iii) a plug electrically-conductive member (W) connected to the plug conductor ring (**30'**), the plug electrically-conductive member (W) within the plug body (**22**) and exiting an end of the plug body (**22**); and

iv) an electrically-conductive contact (**100'**) contacting the plug conductor ring (**30'**), at least a portion of the electrically-conductive contact (**100'**) is in the annular groove (**51'**), the electrically-conductive contact (**100'**) having a generally annular, polygonal-shaped profile and comprising a plurality of substantially straight segments (**102***s'*) joined by a plurality of rounded corners (**102***c'*) defining an axial opening, the electrically-conductive contact (**100'**) being discontinuous and having first and second ends (**104***f*, **104***s'*) received in the annular groove (**51'**), the electrically-conductive contact (**100'**) having a relaxed position and an elastically-deformed position,

in the relaxed position, the electrically-conductive contact (**100'**) has a relaxed inscribed diameter (**102***d'*) that is larger than the outer diameter of the plug conductor ring (**30'**),

in the elastically-deformed position, the electrically-conductive contact (**100'**) is elastically deformed within the axial inner bore (**50***b'*) by the receptacle conductor ring (**50'**), the receptacle conductor ring (**50'**) contacting the electrically-conductive contact (**100'**) and electrical contact is achieved between the plug conductor ring (**30'**) and the receptacle conductor ring (**50'**), and

upon removal of the receptacle conductor ring (**50'**) from contact with the electrically-conductive contact (**100'**), the electrically-conductive contact (**100'**) returns to the relaxed position.

25. The electrical connector (**10'**) of claim **24**, wherein the first and second ends (**104***f*, **104***s'*) are at a mid-portion of one substantially straight segment (**102***s'*).

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