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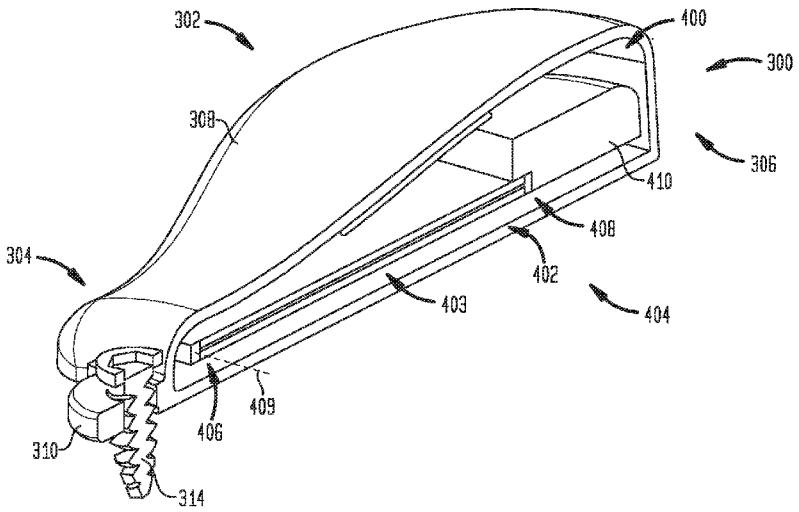
(54) Title: ASYMMETRIC BONE CONDUCTION DEVICE

FIG. 6



(57) Abstract: An asymmetrical implantable medical device includes a housing configured to enclose a piezoelectric bender. The piezoelectric bender includes a fixed end coupled to the housing and a free end configured to flex relative to the fixed end to move relative to the housing. The housing includes a first end configured to enclose the fixed end of the piezoelectric bender and a second end configured to enclose the free end of the piezo electric bender. The first end and the second end of the housing are asymmetrical to one another.

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ASYMMETRIC BONE CONDUCTION DEVICE

BACKGROUND

Field of the Invention

[0001] The present disclosure relates generally to bone conduction devices.

Related Art

[0002] Medical devices have provided a wide range of therapeutic benefits to recipients over recent decades. Medical devices can include internal or implantable components/devices, external or wearable components/devices, or combinations thereof (e.g., a device having an external component communicating with an implantable component). Medical devices, such as traditional hearing aids, partially or fully-implantable hearing prostheses (e.g., bone conduction devices, piezoelectric actuators, cochlear implants, *etc.*), pacemakers, defibrillators, functional electrical stimulation devices, and other medical devices, have been successful in performing lifesaving and/or lifestyle enhancement functions and/or recipient monitoring for a number of years.

[0003] The types of medical devices and the ranges of functions performed thereby have increased over the years. For example, many medical devices, sometimes referred to as "implantable medical devices," now often include one or more instruments, apparatus, sensors, processors, controllers or other functional mechanical or electrical components that are permanently or temporarily implanted in a recipient. These functional devices are typically used to diagnose, prevent, monitor, treat, or manage a disease/injury or symptom thereof, or to investigate, replace or modify the anatomy or a physiological process. Many of these functional devices utilize power and/or data received from external devices that are part of, or operate in conjunction with, implantable components.

SUMMARY

[0004] In one aspect, an implantable medical device is provided. The implantable medical device includes a piezoelectric bender having a fixed end and a free end, opposite the fixed end. The free end is configured to flex relative to the fixed end. The implantable medical device also includes a housing configured to enclose the piezoelectric bender. The housing includes a first end configured to enclose the fixed end and a second end configured to enclose the free end. The first end includes a first dimension, and the second end includes a second dimension that is greater than the first dimension.

[0005] In another aspect, a method for implanting an implantable component of a bone conduction device in a recipient is provided. The implantable component includes a piezoelectric bender and a housing that encloses the piezoelectric bender, and the housing includes a first end having a first dimension and a second end having a second dimension that is greater than the first dimension. The method includes surgically forming a cavity in a skull of the recipient and inserting the implantable component into the cavity to position the first end of the housing of the implantable component proximate to an ear canal of the recipient and to position the second end of the housing distal to the ear canal of the recipient.

[0006] In yet another aspect, a medical device is provided. The medical device includes a piezoelectric element having a first end and a second end, a bone fixture configured to secure the first end of the piezoelectric element to a skull bone of a recipient, a mass attached to the second end of the piezoelectric element, and an asymmetrical housing configured to enclose the piezoelectric element and the mass. The mass is configured to move relative to the first end in response to bending of the piezoelectric element.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] Embodiments of the present invention are described herein in conjunction with the accompanying drawings, in which:

[0008] FIG. 1 is a perspective view of an exemplary bone conduction device, in accordance with certain embodiments presented herein;

[0009] FIG. 2 is a functional block diagram of a bone conduction device, in accordance with certain embodiments presented herein;

[0010] FIG. 3 is a side view of an exemplary bone conduction device implemented in a recipient, in accordance with certain embodiments presented herein;

[0011] FIG. 4 is a perspective view of an exemplary asymmetrical implantable component of a bone conduction device, in accordance with certain embodiments presented herein;

[0012] FIG. 5 is a side view of the asymmetrical implantable component of FIG. 4;

[0013] FIG. 6 is a perspective cross-sectional view of the asymmetrical implantable component of FIG. 4;

[0014] FIG. 7 is a side cross-sectional view of the asymmetrical implantable component of FIG. 4;

[0015] FIG. 8 is a perspective cross-sectional view of an internal assembly of the asymmetrical implantable component of FIG. 4; and

[0016] FIG. 9 is a flowchart of a method for implanting an asymmetrical implantable component of a bone conduction device in a recipient, in accordance with certain embodiments presented herein.

DETAILED DESCRIPTION

[0017] Presented herein are bone conduction devices having an asymmetrical implantable component. The asymmetrical implantable component includes an asymmetrical housing and a mechanical actuator/transducer disposed within the asymmetrical housing having a first end coupled to a rigid structure (e.g., bone) of the recipient, and an opposing second end. During operation of the asymmetrical implantable component, the mechanical actuator generates vibrations that are output by the asymmetrical implantable component at the first end and transferred to a cochlea of the recipient to evoke perception of a sound by the recipient. The first end of the asymmetrical housing is relatively smaller than the second end, where the smaller size of the first end enables the first end (e.g., where the vibrations are output) to be positioned adjacent to an ear canal of the recipient, and therefore more adjacent to the cochlea. The adjacent positioning of the first end of the asymmetrical housing relative to the cochlea enables the vibrations output by the asymmetrical implantable component at the first end to be efficiently transferred to the cochlea.

[0018] Merely for ease of description, the techniques presented herein are primarily described with reference to a specific hearing device in the form of an active transcutaneous bone conduction device. However, it is to be appreciated that the techniques presented herein could also or alternatively be implemented in/with a number of other types of medical devices. For example, the techniques presented herein could be implemented in other types of hearing devices, where the term "hearing device" is to be broadly construed as any device that acts on an actual or potential auditory perception of an individual, including to improve perception of sound signals, to reduce perception of sound signals, etc. In particular, a hearing device can deliver sound signals to a user in any form, including in the form of acoustical stimulation, mechanical stimulation, electrical stimulation, etc., and/or can operate to suppress all or some sound signals. As such, a hearing device can be a device for use by a hearing-impaired person (e.g., hearing aids, middle ear auditory prostheses, bone conduction devices, direct acoustic

stimulators, electro-acoustic hearing prostheses, auditory brainstem stimulators, bimodal hearing prostheses, bilateral hearing prostheses, dedicated tinnitus therapy devices, tinnitus therapy device systems, combinations or variations thereof, etc.), a device for use by a person with normal hearing (e.g., consumer devices that provide audio streaming, consumer headphones, earphones, and other listening devices), a hearing protection device, etc. In other examples, the techniques presented herein can be implemented by, or used in conjunction with, various implantable medical devices, such as vestibular devices (e.g., vestibular implants), visual devices (i.e., bionic eyes), sensors, pacemakers, drug delivery systems, defibrillators, functional electrical stimulation devices, catheters, seizure devices (e.g., devices for monitoring and/or treating epileptic events), sleep apnea devices, electroporation devices, etc.

[0019] FIG. 1 is a perspective view of an active transcutaneous bone conduction device 100 in which certain embodiments presented herein may be implemented. As shown, a recipient of the bone conduction device 100 has an outer ear 101, a middle ear 102, and an inner ear 103. In a fully functional human hearing anatomy, the outer ear 101 includes an auricle 105 and an ear canal 106. A sound wave or acoustic pressure 107 is collected by the auricle 105 and channeled into and through the ear canal 106. Disposed across the distal end of the ear canal 106 is a tympanic membrane 104, which vibrates in response to the sound wave 107. This vibration is coupled to an oval window or fenestra ovalis 110 through three bones of the middle ear 102, collectively referred to as ossicles 111 (e.g., an ossicular chain) and including a malleus 112, incus 113, and stapes 114. The ossicles 111 of the middle ear 102 serve to filter and amplify the sound wave 107, causing the oval window 110 to vibrate. Such vibration sets up waves of fluid motion within a cochlea 139. Such fluid motion, in turn, activates hair cells (not shown) that line the inside of the cochlea 139. Activation of the hair cells causes appropriate nerve impulses to be transferred through spiral ganglion cells and auditory nerve 116 to the brain (not shown), where they are perceived as sound.

[0020] FIG. 1 also illustrates the positioning of the bone conduction device 100 relative to the outer ear 101, the middle ear 102, and the inner ear 103 of the recipient. The bone conduction device 100 includes an external component 118, which is positioned behind the outer ear 101 of the recipient and includes one or more sound input elements 126 to receive sound signals. The sound input elements 126 may include, for example, a microphone, a telecoil, etc. In an exemplary embodiment, the sound input element 126 is a microphone located, for example, on or in the external component 118. Alternatively, the sound input element 126 could be located on a cable extending from the external component 118, physically separated from a remainder

of the external component 118 (e.g., an in-the-ear microphone in wireless communication with another component of the external component 118). The sound input elements 126 convert received sound signals (e.g., the sound wave 107) into drive signals. These drive signals are processed by a sound processor (not shown) of the external component 118.

[0021] The bone conduction device 100 also includes an asymmetrical implantable component 120, which is configured to be implanted within the recipient, such as within the skin/tissue adjacent to the outer ear 101 and fixed to a rigid structure, such as a temporal bone 136, of the recipient. The asymmetrical implantable component 120 includes a coil 122 and an actuator 124 (e.g., a vibrating actuator). The coil 122 is typically a wire antenna coil that includes multiple turns of electrically insulated single-strand or multi-strand platinum or gold wire. The electrical insulation of the coil 122 is provided by a flexible molding (e.g., silicone molding). The external component 118 and the asymmetrical implantable component 120 are configured to magnetically engage one another to enable the external component 118 and the asymmetrical implantable component 120 to communicate with one another. For example, each of the external component 118 and the asymmetrical implantable component 120 includes a magnet and/or is composed of a magnetic material that enables the external component 118 and the asymmetrical implantable component 120 to magnetically attract one another. The magnetic engagement between the external component 118 and the asymmetrical implantable component 120 positions the external component 118 against the skin of the recipient and adjacent to the coil 122 of the asymmetrical implantable component 120.

[0022] In general, the coil 122 enables receipt of power and data from the external component 118 and, potentially, transfer of data to the external component 118. However, it is to be appreciated that various types of energy transfer, such as infrared (IR), electromagnetic, capacitive, and inductive, may be used to transfer power and/or data between the external component 118 and the asymmetrical implantable component 120. By way of example, the external component 118 provides the drive signals processed by the sound processor to the coil 122 of the asymmetrical implantable component 120. The asymmetrical implantable component 120 (e.g., a signal generator, another sound processor) then generates electrical signals based on the drive signals received from the external component 118. The actuator 124 receives the electrical signals, converts the electrical signals into vibrations, and delivers the vibrations to the recipient via the ossicles 111. For instance, the actuator 124 imparts motion onto the temporal bone 136 to which the asymmetrical implantable component 120 is mounted, and such motion is conducted along the temporal bone 136 and to the ossicles 111. The

vibration imparted to the ossicles 111 by the actuator 124 will, in turn, cause the oval window 110 to articulate (vibrate) in response thereto. Similar to the case with normal hearing, the vibration of the oval window 110 sets up waves of fluid motion of the perilymph within the cochlea 139 to, in turn, activate the hair cells inside of the cochlea 139 and enable perception of sound by the recipient.

[0023] FIG. 2 is a functional block diagram of the bone conduction device 100 illustrating further details regarding how sound signals are used to generate vibrations for delivery to the recipient, in accordance with certain embodiments presented herein. As noted, the bone conduction device 100 includes an external component and an asymmetrical implantable component that communicate with one another to generate and deliver the vibrations. The bone conduction device 100 includes the one or more sound input elements 126, an electronics module 152, the actuator 124, a power module 154, and a user interface module 156. In operation, the sound input element(s) 126 (e.g., microphone) are configured to receive sound waves (sound) 107 and to convert the received sound signals into drive signals 158. The sound input element(s) 126 output the drive signals 158 to the electronics module 152.

[0024] The electronics module 152 is configured to convert the drive signals 158 into electrical signals 160 (e.g., adjusted/processed drive signals). That is, the electronics module 152 is configured to apply one or more processing operations (e.g., filtering, noise reduction, automatic gain control/adjustment, loudness compression) to the drive signals 158. In certain embodiments, the electronics module 152 may include a digital signal processor.

[0025] The electronics module 152 provides the electrical signals 160 to the actuator 124. The electrical signals 160 drive (activate) the actuator 124 that, in turn, generate corresponding vibrations. That is, using the electrical signals 160, the actuator 124 generates a mechanical output force that is delivered to the temporal bone of the recipient. Delivery of this output force causes one or more of motion of vibration of the recipient's temporal bone and ossicles, thereby activating the hair cells in the cochlea via cochlea fluid motion and, in turn, evoking perception by the recipient of the received sound waves 107. In certain embodiments, the electrical signals 160 may be amplified (i.e., the time-varying voltage or current is increased), and the amplified electrical signals 160 are provided to the actuator 124 to generate the vibrations.

[0026] As noted, the bone conduction device 100 includes a power module 154. The power module 154 (e.g., a battery or other energy storage component) provides electrical power to

various components of the bone conduction device 100. For ease of illustration, the power module 154 has been shown as being connected to the electronics module 152 and to the user interface module 156. However, it should be noted that the power module 154 can be used to supply power to any electrically powered circuits/components of the bone conduction device 100, including the sound input element(s) 126, the actuator 124, etc.

[0027] The user interface module 156 of the bone conduction device 100 allows the recipient or other user to interact with the bone conduction device 100. For example, the user interface module 156 can allow the recipient to adjust the volume, alter the speech processing strategies, power on/off the bone conduction device 100, etc. The bone conduction device 100 further includes an external interface module 162. The external interface module 162 can be used to connect the electronics module 152 to a separate device, such as a fitting system. Using the external interface module 162, the separate device can obtain information from the bone conduction device 100 (e.g., current parameters, data, alarms) and/or modify parameters of the bone conduction device 100 used in processing received sounds and/or performing other functions.

[0028] FIG. 3 is a side view of the bone conduction device 100 that includes the external component 118 and the asymmetrical implantable component 120. The asymmetrical implantable component 120 is implanted within the recipient, such as beneath fat 128 and skin 132 of the recipient, within muscle 134 of the recipient, and onto the temporal bone 136 of the recipient. The external component 118 is configured to be held against the skin 132 of the recipient, such as via magnetic engagement with the asymmetrical implantable component 120.

[0029] The external component 118 includes the one or more sound input elements 126. In operation, the sound input element(s) 126 convert sound into drive signals to be provided to the actuator 124 through the skin 132 of the recipient via a transmitter coil 200. For instance, the transmitter coil 200 uses a magnetic inductance link to transmit the drive signals to an implanted receiver coil 202 of the asymmetrical implantable component 120 located in coil housing 204 of the asymmetrical implantable component 120. To this end, the implanted receiver coil 202 is made of a ferromagnetic material, that can be in the form of a permanent magnet that generates and/or is reactive to a magnetic field, or that otherwise permits the establishment of a magnetic attraction between the external component 118 and the asymmetrical implantable component 120 to hold the external component 118 against the skin 132 of the recipient. Components (not shown) in the coil housing 204, such as a signal generator or an implanted sound processor, then generate electrical signals to be delivered to

the actuator 124 via an electrical lead assembly 206. The actuator 124 is configured to convert electrical signals into vibration to facilitate perception of sound by the recipient.

[0030] The actuator 124 is disposed within and mechanically coupled to an actuator housing 208. The actuator housing 208 and the actuator 124 collectively form a vibrating element. The actuator housing 208 is substantially rigidly attached to a bone fixture 210, such as via a fastener 212. To this end, the actuator housing 208 includes a through hole that is contoured to the outer contours of the bone fixture 210. That is, the through hole thus forms a bone fixture interface section that is contoured to the exposed section of the bone fixture 210 to enable coupling of the bone fixture 210 to the actuator housing 208. In an exemplary embodiment, the sections are sized and dimensioned such that at least a slip fit or an interference fit exists with respect to the sections. The fastener 212 then compresses the actuator housing 208 against the bone fixture 210. As such, the actuator housing 208, such as a silicon layer 214 of the actuator housing 208, is in abutment with the temporal bone 136 to mechanically couple the actuator 124 to the temporal bone 136. Because the actuator 124 is mechanically coupled to the temporal bone 136, the vibrations output by the actuator 124 are transferred to the temporal bone 136 and eventually to the cochlea.

[0031] As noted, an actuator (e.g., vibrating actuator) disclosed herein has a particular shape to facilitate implementation and/or operation of an asymmetrical implantable component. For example, the actuator is asymmetrically shaped and includes a first end having a smaller dimension than a second end that is disposed opposite to the first end. The smaller dimension of the first end relative to the second end enables the first end to be positioned relatively closer to a cochlea of a recipient than an actuator having a larger first end (e.g., a first end having a similarly sized dimension as that of the second end) to improve efficient operation of the actuator to output vibrations that move the cochlea. Additionally or alternatively, the first end is shaped to enable a fastener to extend therethrough to secure the actuator to the recipient. Thus, the fastener is positioned away from a more centrally located internal volume to enable other components of the actuator to be positioned within the internal volume, thereby facilitating ease of packaging the components of the actuator.

[0032] FIG. 4 is a perspective view of an asymmetrical implantable component 300 of a bone conduction device, in accordance with certain embodiments presented herein. FIG. 5 is a side view of the asymmetrical implantable component 300. For ease of description, FIGs. 4 and 5 will generally be described together.

[0033] The asymmetrical implantable component 300 includes an asymmetrical housing 302 configured to enclose and shield internal components of the asymmetrical implantable component 300. For example, the asymmetrical housing 302 protects the internal components from dust, debris, liquid, and any other elements to prolong a useful lifespan of the internal components. The asymmetrical housing 302 includes a first end 304 and a second end 306. The asymmetrical housing 302 also includes a main body 308 extending between the first end 304 and the second end 306. The main body 308 defines an internal volume in which the internal components of the asymmetrical implantable component 300 are disposed.

[0034] The first end 304 is configured to secure to a recipient of the asymmetrical implantable component 300, such as to a rigid structure (e.g., the temporal bone). To this end, the asymmetrical housing 302 includes a mounting portion 310 (e.g., a flange, a lip) extending from the main body 308 at the first end 304. The mounting portion 310 includes a hole 312 extending therethrough. The hole 312 is configured to receive a fastener 314 (e.g., a screw) that secures the asymmetrical housing 302 to the rigid structure. For example, the fastener 314 is tightened to provide a force that compresses the mounting portion 310, and therefore the asymmetrical housing 302, against a fixture (e.g., the bone fixture 210) coupled to the rigid structure of the recipient. Additionally, the fastener 314 is positioned to secure the asymmetrical housing 302 to the recipient via the mounting portion 310 without extending through the internal volume of the asymmetrical housing 302. That is, because the mounting portion 310 extends away from the main body 308, the fastener 314 inserted through the mounting portion 310 is external and offset from the internal volume defined by the main body 308. As further discussed herein, such an arrangement to position the fastener 314 away from the internal volume enables more efficient usage of the internal volume to facilitate ease of packaging of the internal components within the internal volume.

[0035] During operation, the asymmetrical implantable component 300 (e.g., a piezoelectric actuator positioned within the internal volume of the main body 308) outputs vibrations that propagate through the rigid structure to which the asymmetrical housing 302 is secured. The vibrations are conducted through the rigid structure and to the ossicles, and the vibrations of the ossicles cause the cochlea of the recipient to move, thereby activating hair cells to enable the recipient to perceive sound.

[0036] In this example, as shown in FIG. 4, the first end 304 includes a first dimension 316 (e.g., a first width), and the second end 306 includes a second dimension 318 (e.g., a second width). The first dimension 316 is smaller than the second dimension 318. In addition, as

shown in FIG. 5, first end 304 includes a third dimension 350 (e.g., a first height/thickness) and the second end 306 includes a fourth dimension 352 (e.g., a second height/thickness), and the third dimension 350 is smaller than the fourth dimension 352. As such, the first end 304 is asymmetrical to the second end 306 about a first central axis 320 (shown in FIG. 4) extending along the first dimension 316 and the second dimension 318 and bisecting the main body 308. Additionally, such a configuration of the first end 304 relative to the second end 306 causes the first end 304 to be asymmetrical to the second end 306 about a second central axis 354 (shown in FIG. 5) extending along the third dimension 350 and the fourth dimension 352 and bisecting the main body 308.

[0037] The smaller size of the first end 304 relative to the second end 306 enables the first end to be positioned at a location within the recipient that improves operation of the asymmetrical implantable component 300, namely more adjacent to the cochlea of the recipient. By way of example, skin around an ear canal of the recipient may be susceptible to various structural or geometric changes caused by modifications made in a surrounding area. For instance, placing an implant within a threshold distance of the ear canal can cause the skin around the ear canal to stretch, which may then cause discomfort to the recipient. Thus, it is desirable to place the implant at a position beyond the threshold distance of the ear canal. However, the reduced size of the first end 304 enables the asymmetrical implantable component 300 to be positioned closer to the ear canal without affecting the structure or geometry of the skin around the ear canal (e.g., without stretching the skin). In other words, reducing the first dimension 316 also reduces the threshold distance at which the asymmetrical implantable component 300 can be positioned with respect to the ear canal.

[0038] Positioning of the asymmetrical implantable component 300 closer to the ear canal positions the asymmetrical implantable component 300 closer to the cochlea of the recipient. As a result, the vibrations output by the asymmetrical implantable component 300 have a shorter path of travel to cause movement of the cochlea more efficiently. That is, the shorter path of travel of the vibrations through the bones of the recipient reduces mechanical loss of the vibrations (e.g., absorption of the vibrations by the bones, dissipation of the vibrations into tissue of the recipient). In other words, greater integrity of the vibrations is maintained to provide greater movement of the cochlea for activating the hair cells and enabling sound perception. As such, the asymmetrical implantable component 300 can more directly move the cochlea.

[0039] Additionally, the asymmetric profile of the asymmetrical implantable component 300 in which the first end 304 is smaller than the second end 306 may reduce a cost of manufacture of the asymmetrical implantable component 300. By way of example, a relative smaller amount of material may be used to manufacture the asymmetrical housing 302 of the asymmetrical implantable component 300 as compared to an implantable component having a housing that includes ends with similar dimensions or that is otherwise symmetrical. Indeed, the first end 304 and the second end 306 may enclose different components and/or different parts of a component having different sizes, and the first end 304 and the second end 306 may therefore be manufactured to have different sizes that sufficiently accommodates positioning of the components therein.

[0040] In the illustrated embodiment, the second end 306 has a more curved (e.g., circular) profile and the first end 304 has a more linear or prismatic profile. In this manner, the main body 308 has a geometrically oval stadium shape, a balloon-like shape, or a rounded trapezoidal geometry. However, it should be noted that the asymmetrical implantable component 300 can have any other suitable profile in which the first end 304 has a smaller dimension than the second end 306, such as a triangular shape.

[0041] The asymmetrical implantable component 300 includes a first surface 356 (e.g., a bone engaging surface) and a second surface 358, opposite, the first surface 356. Each of the first surface 356 and the second surface 358 extends from the first end 304 to the second end 306. The first surface 356 has a planar or linear profile in the illustrated embodiment to facilitate abutment of the first surface 356 against the rigid structure of the recipient. For example, the flat configuration of the first surface 356 can enable the first surface 356 to be positioned flush against the rigid structure, thereby facilitating securement of the asymmetrical implantable component 300 within the recipient. In additional or alternative embodiments, the first surface 356 can have a different geometry, such as a curved, stepped, or other suitable geometry, that enables positioning of the first surface 356 onto the rigid structure of the recipient. For instance, the first surface 356 can have a contour that matches that of the rigid structure to facilitate positioning of the first surface 356 against the rigid structure and therefore securement of the asymmetrical implantable component 300 within the recipient. Moreover, the second surface 358 has a generally curved profile. Such a profile of the second surface 358 enables the main body 308 to define a suitably sized internal volume in which other components of the asymmetrical implantable component 300 are positioned. By way of example, extension of the second surface 358 between the first end 304 and the second end 306 provides sufficient

space that enables the other components to be positioned within the main body 308 and to move or flex relative to the asymmetrical housing 302.

[0042] Furthermore, the mounting portion 310 of the asymmetrical implantable component 300 has a fifth dimension 360 (e.g., a third height) that is smaller than the third dimension 350 and the fourth dimension 352. The reduced size of the mounting portion 310 may further facilitate securement of the asymmetrical implantable component 300 within the recipient and/or reduce a cost of manufacture of the asymmetrical implantable component 300. For example, the reduced size of the mounting portion 310 enables a smaller sized fastener 314 (e.g., having a shorter length) to be inserted through the mounting portion 310 to couple to the rigid structure. Additionally, the reduced size of the mounting portion 310 reduces an amount of material used to manufacture the mounting portion 310, such as in comparison to a mounting portion having a similar dimension as the third dimension 350 or the fourth dimension 352.

[0043] FIG. 6 is a perspective cross-sectional view of the asymmetrical implantable component 300. As shown, the main body 308 of the asymmetrical housing 302 defines an internal volume 400 (e.g., a chamber) in which an internal assembly 402 is disposed. The internal assembly 402 includes a piezoelectric actuator 404 which includes a piezoelectric bender 403 configured to bend within the internal volume 400 during operation of the asymmetrical implantable component 300. The piezoelectric bender 403 is formed from two or more piezoelectric elements and the piezoelectric bender 403 can have, for example, two-layer / three-layer design, a cofired multilayer construction, etc. The bending motion of the piezoelectric bender 403 is caused by one layer being operated in contraction mode, while the other layer is expanding.

[0044] As shown, the piezoelectric bender 403 has a fixed end 406, which is secured to the first end 304 of the asymmetrical housing 302, such as via an interference fit, a fastener, an adhesive, another feature, or any combination thereof. The piezoelectric bender 403 also includes a free end 408, which is enclosed by the second end 306 of the asymmetrical housing 302. During operation of the asymmetrical implantable component 300, the free end 408 of the piezoelectric bender 403 is configured to flex or bend relative to the fixed end 406 of the piezoelectric bender 403 as a result of received electrical signals (e.g., provided by a signal generator). For example, at least a portion of the piezoelectric bender 403 may generally rotate about an axis 409 extending through the fixed end 406 (e.g., and extending along the first dimension 316 and/or the second dimension 318). Movement of the free end 408 relative to the fixed end 406 transfers a force along the piezoelectric bender 403 to the fixed end 406 to

output vibrations at the fixed end 406, and the vibrations transfer from the fixed end 406 to the first end 304 of the asymmetrical housing 302, to the mounting portion 310, to the fastener 314, and to the rigid structure of the recipient to cause movement of the cochlea.

[0045] The internal assembly 402 also includes a mass 410 coupled to the free end 408 of the piezoelectric bender 403. The mass 410 facilitates output of vibrations by the piezoelectric actuator 404. For example, the mass 410 increases transfer of force along the piezoelectric bender 403 to the fixed end 406 during movement of the piezoelectric bender 403 within the asymmetrical housing 302, thereby increasing the vibrations output at the fixed end 406 and eventually conducted to the cochlea of the recipient. In this manner, the mass 410 may improve the sound perceived by the recipient by providing increased movement of the cochlea. The second end 306 of the main body 308 is sized (e.g., having the second dimension 318, having the fourth dimension 352) to accommodate positioning of the mass 410 having a sufficient shape and/or size to enable desirable output of vibrations during operation of the asymmetrical implantable component 300.

[0046] As discussed herein, the asymmetrical implantable component 300 is implanted in the recipient such that the first end 304 of the asymmetrical housing 302 is positioned adjacent to the ear canal and relatively closer to the cochlea. Thus, the vibrations output at the fixed end 406 may conduct more efficiently toward the cochlea. Such positioning of the asymmetrical implantable component 300 in the recipient also arranges the second end 306 of the asymmetrical housing 302 distal to the ear canal and relatively farther away from the cochlea.

[0047] FIG. 7 is a side cross-sectional view of the asymmetrical implantable component 300. As shown in FIG. 7, the fastener 314 is offset from the internal volume 400 and therefore does not extend through the internal volume 400. For this reason, an entirety of the internal volume 400 within the main body 308 is available for positioning of the internal assembly 402. As such, the internal assembly 402 may be more readily manufactured and/or positioned within the internal volume 400. For example, the internal assembly 402 may have any suitable shape and/or be placed at any suitable position without having to accommodate a space occupied by a fastener extending through the internal volume 400. In other words, the internal assembly 402 does not have to have a specific shape and/or be placed at a specific position that avoids contact with a fastener extending through the internal volume 400. As such, an ease of implementation of the internal assembly 402 is improved.

[0048] In FIG. 7, the piezoelectric bender 403 is in an unactuated configuration in which no electrical signals are received. As such, in the unactuated configuration, the free end 408 has an unactuated position in which the piezoelectric actuator 404 is not bent and vibrations therefore are not transferred to the recipient. For instance, the piezoelectric bender 403 may generally extend along (e.g., parallel to) the first surface 356 of the asymmetrical housing 302 in the unactuated position of the free end 408. In the unactuated configuration, an air gap 450 is formed between the piezoelectric bender 403 and a third surface 452 of the asymmetrical housing 302, the third surface 452 being opposite the second surface 358 and facing the internal volume 400. In response to receipt of electrical signals, the piezoelectric bender 403 transitions to an actuated configuration by bending toward the third surface 452, thereby placing the free end 408 in an actuated position. That is, the free end 408 of the piezoelectric bender 403 moves across at least a portion of the air gap 450 in the actuated configuration of the piezoelectric bender 403 to transition to the actuated position. Such movement of the piezoelectric bender 403 also drives movement of the mass 410 relative to the fixed end 406 and toward the third surface 452.

[0049] In certain embodiments, the mass 410 is sized (e.g., to have a particular thickness 454), the second surface 358 is shaped, and/or the internal assembly 402 is positioned within the internal volume 400 to offset the mass 410 from the third surface 452 by a threshold distance 456 in the unactuated configuration of the piezoelectric bender 403. During transition of the piezoelectric bender 403 to the actuated configuration in which the mass 410 is moved toward the third surface 452, the distance between the third surface 452 and the mass 410 is reduced. Indeed, sufficient flexure of the piezoelectric bender 403 may move the mass 410 into contact with the third surface 452. In other words, sufficient flexure of the piezoelectric bender 403 may cause the mass 410 to move the threshold distance 456 onto the third surface 452 and may correspondingly cause the free end 408 to move the threshold distance 456 away from the unactuated position. The asymmetrical housing 302 may then block further movement of the mass 410 and therefore further flexure of the piezoelectric bender 403. That is, the piezoelectric bender 403 has a maximum allowable flexure within the internal volume 400 to move the mass 410 into abutment with the third surface 452, and abutment between the mass 410 and the third surface 452 blocks additional movement of the piezoelectric bender 403 past the maximum allowable flexure. The threshold distance 456 is selected such that the maximum allowable flexure does not reduce the structural integrity of the piezoelectric actuator 404 (e.g., cause elastic deformation or permanent geometric changes to the piezoelectric bender 403),

while still enabling such movement of the piezoelectric bender 403 to output sufficient vibrations to cause the recipient to perceive sound.

[0050] FIG. 8 is a perspective cross-sectional view of the internal assembly 402 of the asymmetrical implantable component 300 coupled to the first end 304 of the asymmetrical housing 302. A remainder of the asymmetrical housing 302 has been omitted to facilitate visualization of the internal assembly 402. In the illustrated embodiment, the piezoelectric bender 403 is attached to the first end 304 of the asymmetrical housing 302 and to the mass 410 via interference fits. However, the piezoelectric bender 403 can additionally or alternatively be attached to the first end 304 of the asymmetrical housing 302 and/or to the mass 410 using any other suitable feature, such as a fastener or an adhesive. The coupling of the piezoelectric bender 403 to the mass 410 enables movement (e.g., flexure) of the piezoelectric bender 403 to drive movement of the mass 410, and the coupling of the piezoelectric bender 403 to the asymmetrical housing 302 enables movement of the piezoelectric bender 403 to transfer vibrations to the asymmetrical housing 302.

[0051] As noted, the piezoelectric bender 403 includes a plurality of layers 500 (e.g., piezoelectric layers, piezoceramic layers). The plurality of layers 500 receives electric signals that cause bending of the piezoelectric bender 403. For example, a first subset 502 of the plurality of layers 500 at a first side 503 of the plurality of layers 500 can receive a first voltage, and a second subset 504 of the plurality of layers 500 at a second side 505, opposite the first side 503, of the plurality of layers 500 can independently receive a second voltage. The voltages cause deformation of the first subset 502 and/or of the second subset 504 of the plurality of layers 500 to cause flexure of the piezoelectric bender 403. By way of example, the voltages can cause relative expansion and contraction of the first subset 502 and/or the second subset 504 of the plurality of layers 500 to cause the piezoelectric bender 403 to bend in a first direction 506 (e.g., toward the third surface 452) or in a second direction 508 (e.g., away from the third surface 452) about the axis 409.

[0052] A voltage being applied to cause bending of the illustrated piezoelectric actuator 404 may be relatively lower than, for example, that used to bend an embodiment in which a central portion of a piezoelectric actuator is coupled to the asymmetrical housing 302 (e.g., an embodiment in which the fastener extends through the internal volume of the housing such that vibrations transfer from the central portion to the fastener). For instance, a resonance frequency used to move the piezoelectric bender 403 to generate vibrations may be relatively lower. In particular, because the fixed end 406 is coupled to the asymmetrical housing 302, a relatively

increased length of the piezoelectric bender 403 is available for movement. That is, the lever arm of the piezoelectric bender 403 is increased. As a result, a relatively lower force (e.g., provided by a relatively lower voltage) can be applied to cause movement of the piezoelectric bender 403. For this reason, less power is used to enable bending of the piezoelectric bender 403, thereby reducing power consumption to operate the asymmetrical implantable component 300 and output vibrations. Thus, a cost associated with operation of the asymmetrical implantable component 300 is also reduced.

[0053] FIG. 9 is a flowchart of a method 550 for implanting an asymmetrical implantable component of a bone conduction device in a recipient. In some embodiments, the operations of the method 550 are manually performed (e.g., by a surgeon). In additional or alternative embodiments, the operations of the method 550 are automatically performed (e.g., by robotic surgical equipment). At block 552, a cavity is surgically formed in a skull of the recipient. For example, the cavity is formed in the temporal bone adjacent to an ear canal of the recipient.

[0054] At block 554, the asymmetrical implantable component is inserted into the cavity. In particular, the asymmetrical implantable component includes an asymmetrical housing having a first end with a first dimension and a second end with a second dimension that is greater than the first dimension. The asymmetrical implantable component is positioned within the cavity such that the first end of the asymmetrical housing is proximate to the ear canal and the second end of the asymmetrical housing is distal to the ear canal.

[0055] At block 556, the asymmetrical implantable component is secured to the skull. By way of example, a fastener is inserted through the asymmetrical housing of the asymmetrical implantable component at the first end of the asymmetrical housing to compress the asymmetrical housing against the skull, thereby securing the asymmetrical implantable component to the skull. Securement of the asymmetrical implantable component to the skull enables the asymmetrical implantable component to output vibrations that cause movement of a cochlea of the recipient to enable the recipient to perceive sound. For instance, the asymmetrical implantable component includes a piezoelectric actuator (e.g., a piezoelectric bender, a piezoelectric element) positioned within and secured to the asymmetrical housing, and the piezoelectric actuator is configured to move (e.g., flex) within the asymmetrical housing during operation of the asymmetrical implantable component. Movement of the piezoelectric actuator causes vibration of the asymmetrical housing, which is then transferred to and along the skull and eventually to the cochlea. Because the first end is positioned proximate to the ear canal, the first end is also positioned more proximate to a cochlea of the

recipient. Thus, the vibrations output by the asymmetrical implantable component more efficiently transfer to the cochlea, thereby increasing efficiency of operation of the asymmetrical implantable component to enable the recipient to perceive sound.

[0056] As should be appreciated, while particular uses of the technology have been illustrated and discussed above, the disclosed technology can be used with a variety of devices in accordance with many examples of the technology. The above discussion is not meant to suggest that the disclosed technology is only suitable for implementation within systems akin to that illustrated in the figures. In general, additional configurations can be used to practice the processes and systems herein and/or some aspects described can be excluded without departing from the processes and systems disclosed herein.

[0057] This disclosure described some aspects of the present technology with reference to the accompanying drawings, in which only some of the possible aspects were shown. Other aspects can, however, be embodied in many different forms and should not be construed as limited to the aspects set forth herein. Rather, these aspects were provided so that this disclosure was thorough and complete and fully conveyed the scope of the possible aspects to those skilled in the art.

[0058] As should be appreciated, the various aspects (e.g., portions, components, etc.) described with respect to the figures herein are not intended to limit the systems and processes to the particular aspects described. Accordingly, additional configurations can be used to practice the methods and systems herein and/or some aspects described can be excluded without departing from the methods and systems disclosed herein.

[0059] According to certain aspects, systems and non-transitory computer readable storage media are provided. The systems are configured with hardware configured to execute operations analogous to the methods of the present disclosure. The one or more non-transitory computer readable storage media comprise instructions that, when executed by one or more processors, cause the one or more processors to execute operations analogous to the methods of the present disclosure.

[0060] Similarly, where steps of a process are disclosed, those steps are described for purposes of illustrating the present methods and systems and are not intended to limit the disclosure to a particular sequence of steps. For example, the steps can be performed in differing order, two or more steps can be performed concurrently, additional steps can be performed, and disclosed

steps can be excluded without departing from the present disclosure. Further, the disclosed processes can be repeated.

[0061] Although specific aspects were described herein, the scope of the technology is not limited to those specific aspects. One skilled in the art will recognize other aspects or improvements that are within the scope of the present technology. Therefore, the specific structure, acts, or media are disclosed only as illustrative aspects. The scope of the technology is defined by the following claims and any equivalents therein.

[0062] It is also to be appreciated that the embodiments presented herein are not mutually exclusive and that the various embodiments may be combined with another in any of a number of different manners.

CLAIMS

What is claimed is:

1. An implantable medical device, comprising:

a piezoelectric bender having a fixed end and a free end, opposite the fixed end, wherein the free end is configured to flex relative to the fixed end; and

a housing configured to enclose the piezoelectric bender, wherein the housing comprises:

a first end configured to enclose the fixed end, wherein the first end comprises a first dimension; and

a second end configured to enclose the free end, wherein the second end comprises a second dimension that is greater than the first dimension.

2. The implantable medical device of claim 1, wherein the first end of the housing is configured to be secured to a rigid structure of a recipient via a fixture.

3. The implantable medical device of claim 1, wherein the free end of the piezoelectric bender is configured to flex relative to the housing.

4. The implantable medical device of claim 3, wherein the piezoelectric bender has an actuated configuration and an unactuated configuration, wherein the implantable medical device includes an air gap extending between the free end and the housing in the unactuated configuration of the piezoelectric bender, and wherein the free end is configured to flex and move across at least a portion of the air gap in the actuated configuration of the piezoelectric bender.

5. The implantable medical device of claim 1, comprising a mass attached to the free end of the piezoelectric bender.

6. The implantable medical device of claim 5, wherein the free end of the piezoelectric bender is configured to flex from an unactuated position to an actuated position to move the mass toward the housing, and wherein the housing is configured to abut against the mass to block flexure of the free end beyond a threshold distance away from the unactuated position.

7. The implantable medical device of claim 1, 2, 3, 4, 5, or 6, wherein the piezoelectric bender comprises:

a plurality of piezoelectric layers comprising a first subset of piezoelectric layers at a first side of the plurality of piezoelectric layers and a second subset of piezoelectric layers at a second side, opposite the first side, of the plurality of piezoelectric layers, wherein each of the first subset of piezoelectric layers and the second subset of piezoelectric layers is configured to receive a voltage that adjusts a size of the first subset of piezoelectric layers relative to a size of the second subset of piezoelectric layers to cause flexure of the free end relative to the fixed end.

8. The implantable medical device of claim 1, 2, 3, 4, 5, or 6, comprising an implantable coil configured to receive drive signals from an external component.

9. The implantable medical device of claim 8, comprising the external component, wherein the external component is configured to generate the drive signals based on one or more sound signals.

10. A method for implanting an implantable component of a bone conduction device in a recipient, wherein the implantable component comprises a piezoelectric bender and a housing that encloses the piezoelectric bender, wherein the housing comprises a first end having a first dimension and a second end having a second dimension that is greater than the first dimension, and wherein the method comprises:

surgically forming a cavity in a skull of the recipient; and

inserting the implantable component into the cavity to position the first end of the housing of the implantable component proximate to an ear canal of the recipient and to position the second end of the housing distal to the ear canal of the recipient.

11. The method of claim 10, comprising securing the implantable component to the skull.

12. The method of claim 10 or 11, wherein securing the implantable component to the skull comprises inserting a fastener through the first end of the housing and into a fixture.

13. A medical device, comprising:

a piezoelectric element having a first end and a second end;

a bone fixture configured to secure the first end of the piezoelectric element to a skull bone of a recipient;

a mass attached to the second end of the piezoelectric element, wherein the mass is configured to move relative to the first end in response to bending of the piezoelectric element; and

an asymmetrical housing configured to enclose the piezoelectric element and the mass.

14. The medical device of claim 13, wherein the asymmetrical housing includes a main body that comprises:

a first end configured to enclose the first end of the piezoelectric element; and

a second end configured to enclose the second end of the piezoelectric element,

wherein the first end of the main body is asymmetrical to the second end of the main body about a central axis that bisects the main body.

15. The medical device of claim 14, wherein a thickness of the first end of the main body is less than a thickness of the second end of the main body.

16. The medical device of claim 13, 14, or 15, wherein the first end of the piezoelectric element is coupled to the asymmetrical housing, and the asymmetrical housing is coupled to the bone fixture to secure the first end of the piezoelectric element to the skull bone.

17. The medical device of claim 16, comprising a fastener extending through the asymmetrical housing and the bone fixture to couple the asymmetrical housing to the bone fixture.

18. The medical device of claim 17, wherein the asymmetrical housing defines an internal volume, wherein the piezoelectric element and the mass are positioned within the internal volume, and wherein the fastener is offset from the internal volume of the asymmetrical housing.

19. The medical device of claim 18, wherein the asymmetrical housing comprises:

a main body that defines the internal volume; and

a mounting portion extending from the main body, wherein the mounting portion includes a hole configured to receive the fastener.

20. The medical device of claim 13, 14, or 15, wherein the asymmetrical housing comprises a planar bone engaging surface configured to abut against the skull bone.

FIG. 1

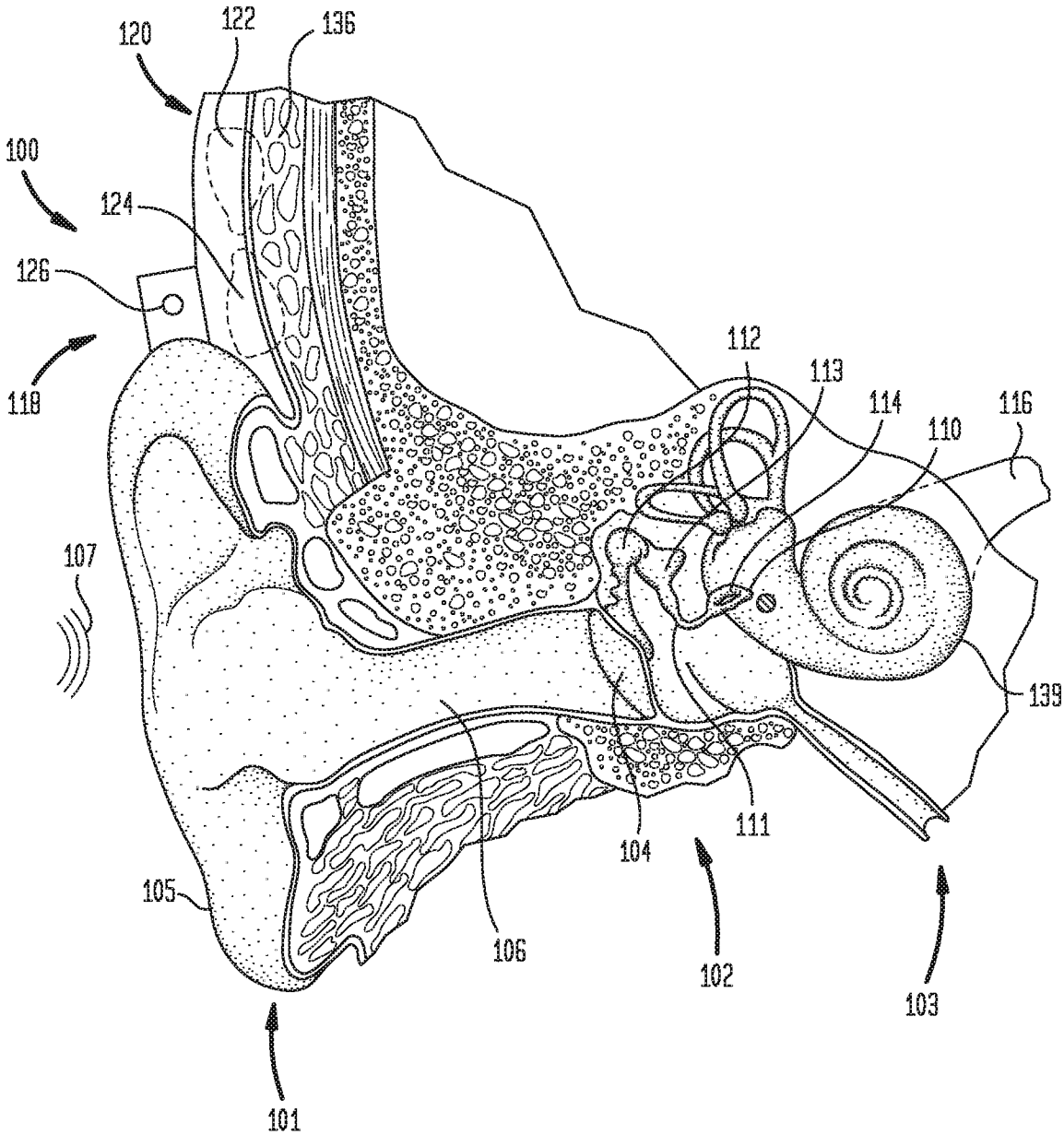
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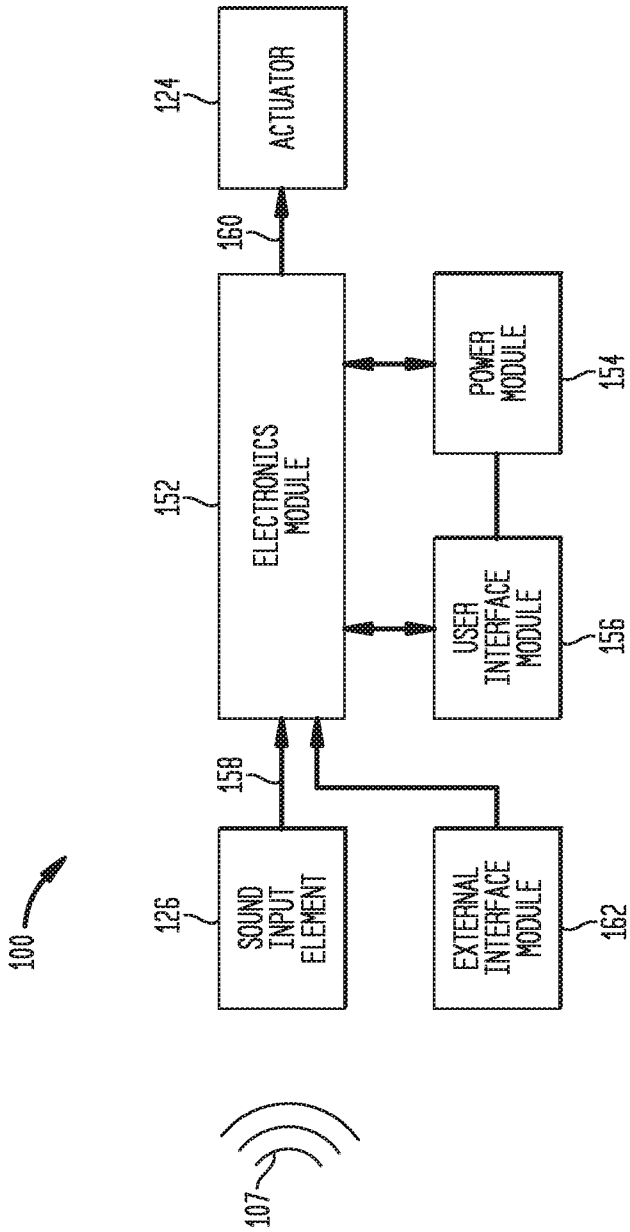
FIG. 2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SOUND INPUT ELEMENT
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152
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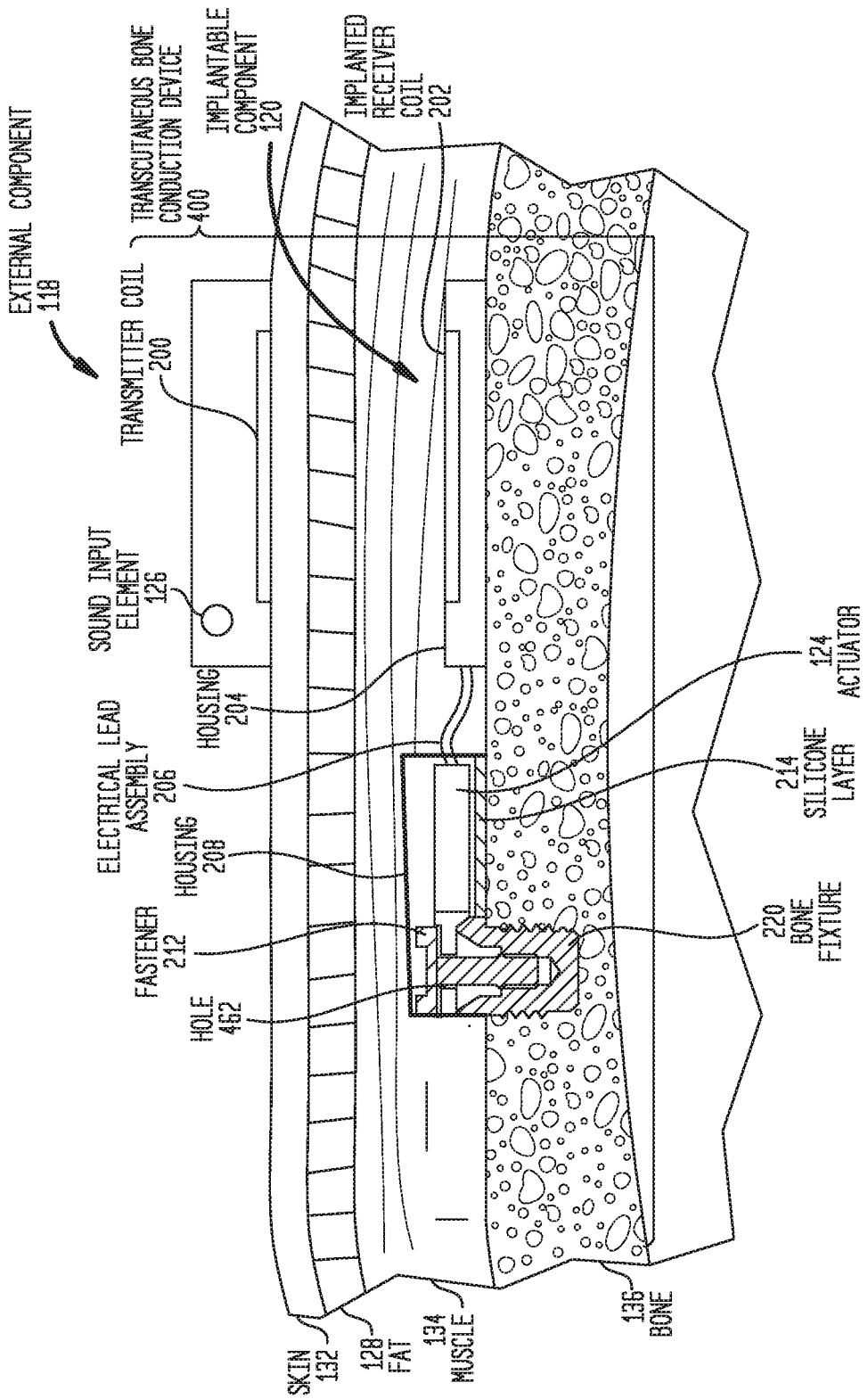
124
ACTUATOR
154
POWER MODULE
156
USER INTERFACE MODULE
162
EXTERNAL INTERFACE MODULE

FIG. 3


EXTERNAL COMPONENT
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TRANSCUTANEOUS BONE CONDUCTION DEVICE
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IMPLANTABLE COMPONENT
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IMPLANTED RECEIVER COIL
202
TRANSMITTER COIL
200
SOUND INPUT ELEMENT
126
HOUSING
204
ELECTRICAL LEAD ASSEMBLY
206
HOUSING
208
FASTENER
212
HOLE
462
124
ACTUATOR
214
SILICONE LAYER
220
BONE FIXTURE
SKIN
132
128
FAT
134
MUSCLE
136
BONE

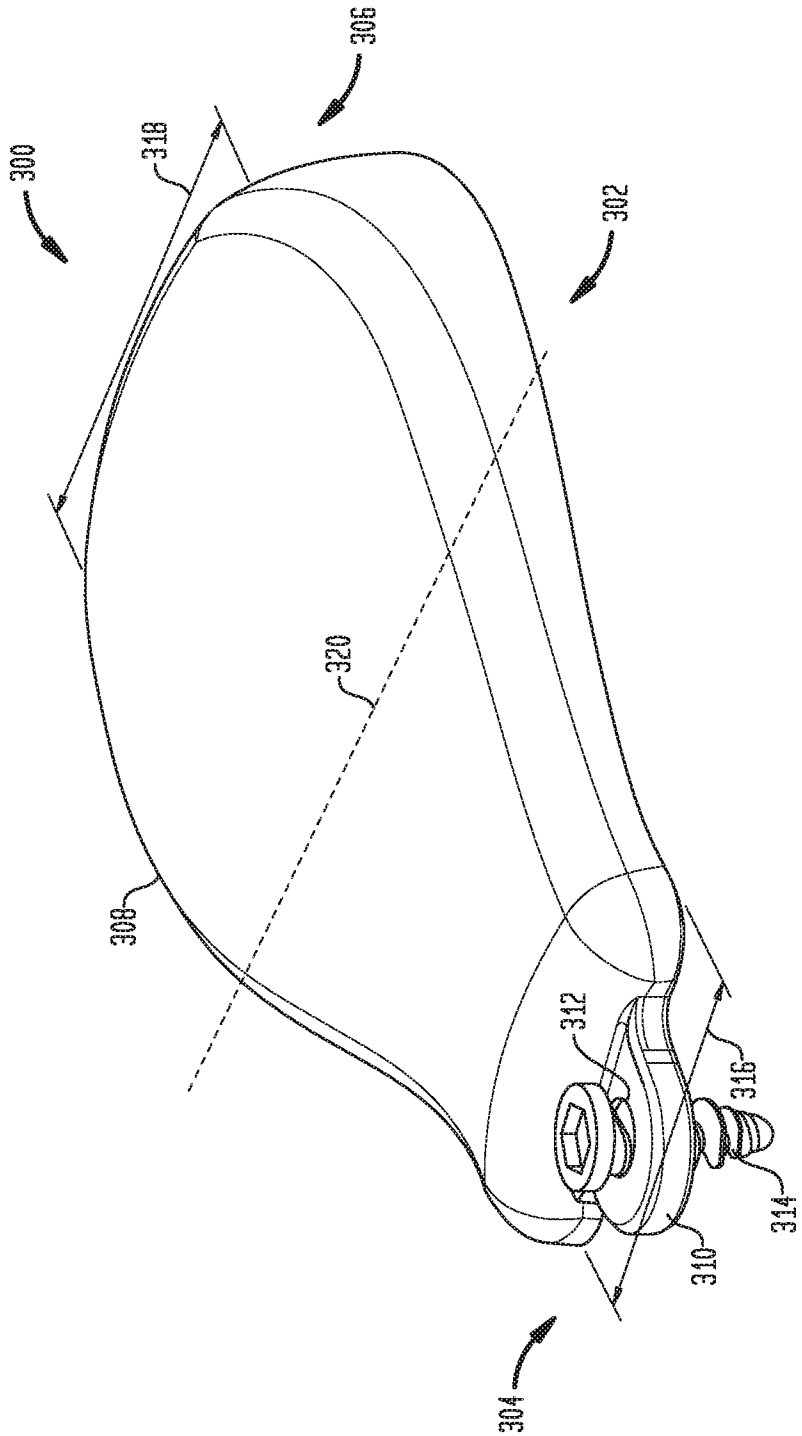


FIG. 4

FIG. 5

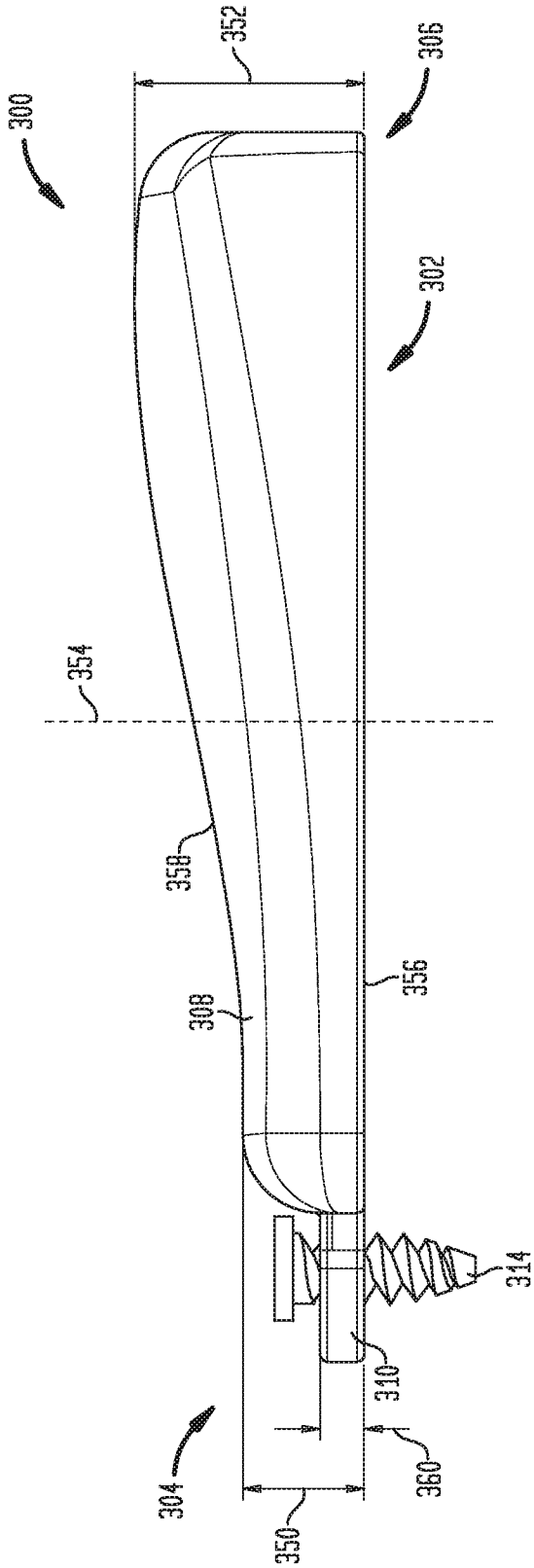
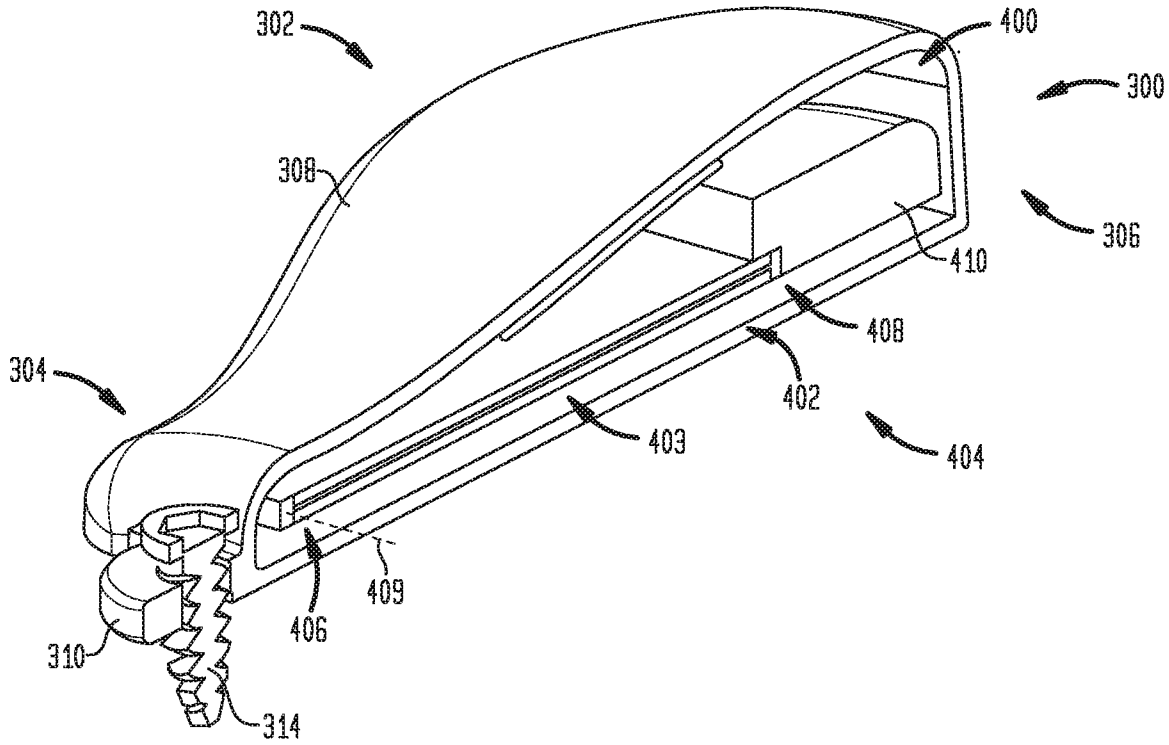
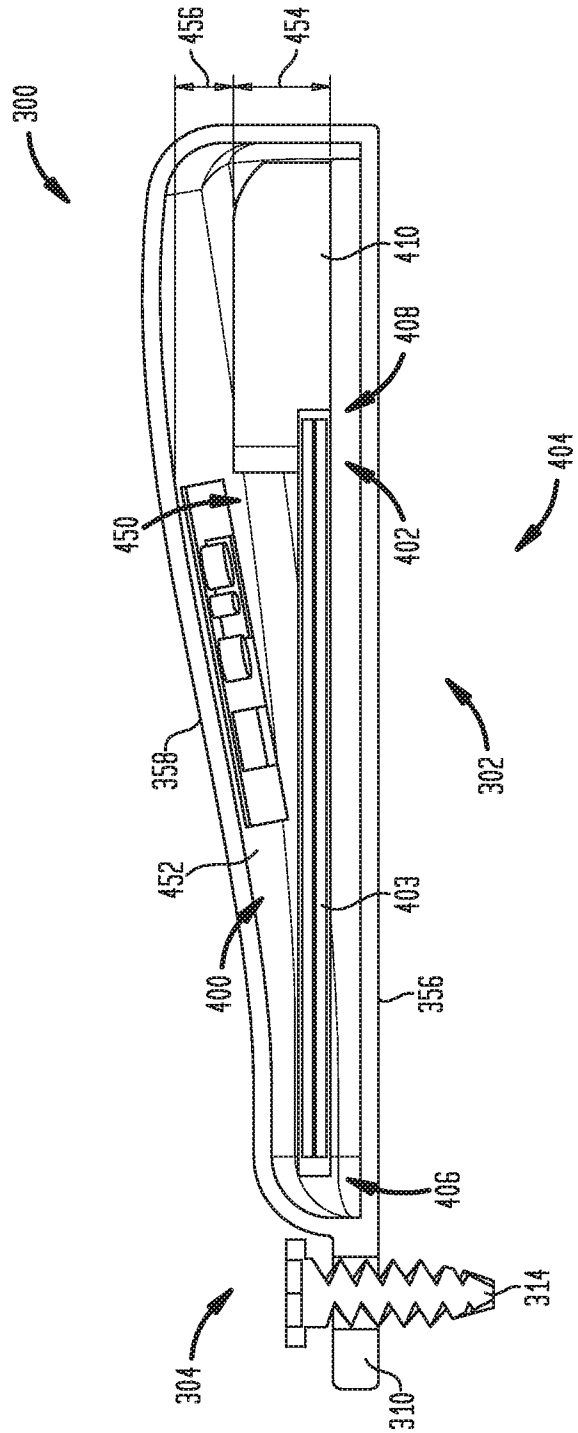


FIG. 6




300
456
454
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408
404
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302
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403
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356
406
314
304
310

FIG. 7

FIG. 8

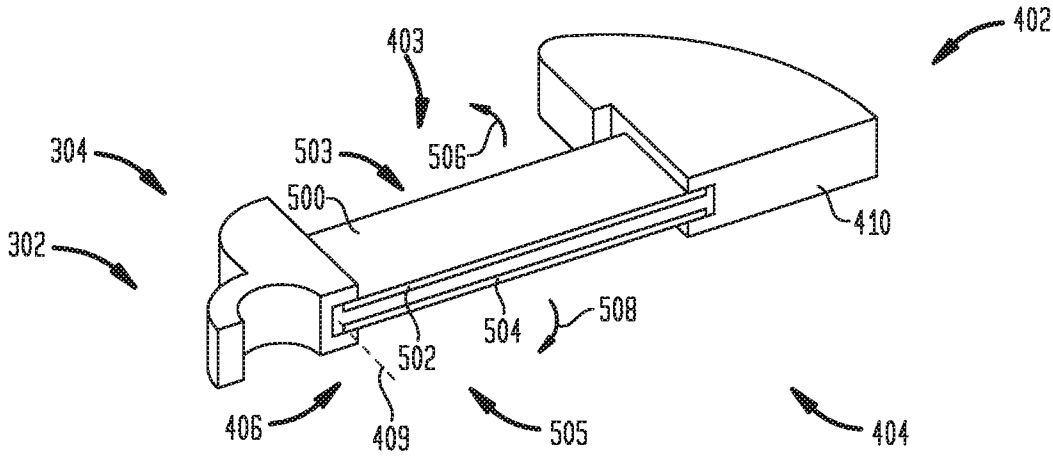
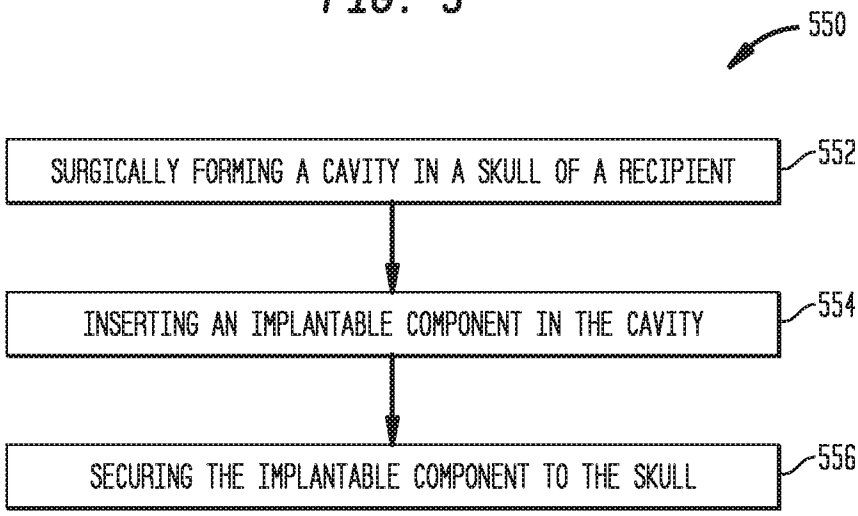


FIG. 9


550
SURGICALLY FORMING A CAVITY IN A SKULL OF A RECIPIENT
552
INSERTING AN IMPLANTABLE COMPONENT IN THE CAVITY
554
SECURING THE IMPLANTABLE COMPONENT TO THE SKULL
556

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2024/055512

A. CLASSIFICATION OF SUBJECT MATTER

A61F 2/28(2006.01)i; **A61F 2/44**(2006.01)i; **A61F 2/30**(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

A61F 2/28(2006.01); A61F 11/04(2006.01); A61F 2/00(2006.01); H04R 17/00(2006.01); H04R 25/00(2006.01)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: asymmetric, housing, bone condcution, implant, piezoelectric, bender, mass, fixture, fastener

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2013-0096366 A1 (BERVOETS, W. et al.) 18 April 2013 (2013-04-18) paragraphs [0041]-[0046], [0091], [0096]; claims 1, 15, 17; figures 1, 2d, 4, 5a, 11	1-9,13-20
Y	US 2016-0183017 A1 (EARLENS CORPORATION) 23 June 2016 (2016-06-23) paragraph [0126]; claims 1, 15; figure 5a	1-9,13-20
Y	WO 2010-142018 A1 (DALHOUSIE UNIVERSITY et al.) 16 December 2010 (2010-12-16) page 6, lines 32-35; claim 4	7
A	US 10477332 B2 (COCHLEAR LIMITED) 12 November 2019 (2019-11-12) claims 1-15	1-9,13-20
A	US 2007-0156011 A1 (WESTERKULL, P.) 05 July 2007 (2007-07-05) paragrapg [0043]; claims 1-15; figure 2	1-9,13-20

☐ Further documents are listed in the continuation of Box C.

☑ See patent family annex.

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

Date of the actual completion of the international search	Date of mailing of the international search report
11 September 2024	**11 September 2024**

Name and mailing address of the ISA/KR	Authorized officer
Korean Intellectual Property Office **189 Cheongsa-ro, Seo-gu, Daejeon** **35208, Republic of Korea**	**HEO, Joo Hyung**
Facsimile No. **+82-42-481-8578**	Telephone No. **+82-42-481-5373**

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IB2024/055512

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☑ Claims Nos.: **10-12**
because they relate to subject matter not required to be searched by this Authority, namely:

Claims 10-12 pertain to methods for treatment of the human body and thus relate to a subject-matter which this International Searching Authority is not required, under PCT Article 17(2)(a)(i) and PCT Rule 39.1(iv), to search.

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IB2024/055512

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
US 2013-0096366 A1	18 April 2013	US 11889272 B2	30 January 2024
		US 2019-0289412 A1	19 September 2019
		WO 2013-054312 A1	18 April 2013
US 2016-0183017 A1	23 June 2016	EP 1787492 A4	16 March 2011
		EP 1880574 A2	23 January 2008
		EP 1880574 A4	15 July 2009
		EP 1880574 B1	06 August 2014
		EP 2206360 A1	14 July 2010
		EP 2206360 A4	19 December 2012
		EP 2208367 A1	21 July 2010
		EP 2208367 A4	23 October 2013
		EP 2208367 B1	27 September 2017
		EP 2301261 A1	30 March 2011
		EP 2301261 A4	06 March 2013
		EP 2301261 B1	06 February 2019
		EP 2301262 A1	30 March 2011
		EP 2301262 A4	06 March 2013
		EP 2301262 B1	27 September 2017
		EP 2342905 A1	13 July 2011
		EP 2342905 B1	02 January 2019
		EP 2802160 A1	12 November 2014
		EP 2802160 B1	21 December 2016
		EP 3509324 A1	10 July 2019
		EP 3509324 B1	16 August 2023
		JP 2008-508039 A	21 March 2008
		JP 2008-541560 A	20 November 2008
		JP 4870669 B2	08 February 2012
		JP 5341507 B2	13 November 2013
		KR 10-1568451 B1	11 November 2015
		KR 10-1568452 B1	20 November 2015
		KR 10-1717034 B1	15 March 2017
		KR 10-2011-0058769 A	01 June 2011
		KR 10-2011-0063732 A	14 June 2011
		KR 10-2011-0086804 A	01 August 2011
		KR 10-2016-0119879 A	14 October 2016
		US 10154352 B2	11 December 2018
		US 10237663 B2	19 March 2019
		US 10511913 B2	17 December 2019
		US 10516946 B2	24 December 2019
		US 10516949 B2	24 December 2019
		US 10516950 B2	24 December 2019
		US 10743110 B2	11 August 2020
		US 10863286 B2	08 December 2020
		US 11057714 B2	06 July 2021
		US 11310605 B2	19 April 2022
		US 11483665 B2	25 October 2022
		US 11805374 B2	31 October 2023
		US 2006-0023908 A1	02 February 2006
		US 2006-0189841 A1	24 August 2006
		US 2006-0251278 A1	09 November 2006

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IB2024/055512

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
		US	2007-0100197	A1	03 May 2007
		US	2009-0092271	A1	09 April 2009
		US	2009-0097681	A1	16 April 2009
		US	2010-0034409	A1	11 February 2010
		US	2010-0048982	A1	25 February 2010
		US	2010-0202645	A1	12 August 2010
		US	2011-0077453	A1	31 March 2011
		US	2012-00014546	A1	19 January 2012
		US	2012-00039493	A1	16 February 2012
		US	2013-0287239	A1	31 October 2013
		US	2014-0003640	A1	02 January 2014
		US	2014-0286514	A1	25 September 2014
		US	2014-0296620	A1	02 October 2014
		US	2015-0010185	A1	08 January 2015
		US	2015-0023540	A1	22 January 2015
		US	2016-0066101	A1	03 March 2016
		US	2016-0134976	A1	12 May 2016
		US	2016-0277854	A1	22 September 2016
		US	2016-0309265	A1	20 October 2016
		US	2017-0134866	A1	11 May 2017
		US	2017-0150275	A1	25 May 2017
		US	2018-0007472	A1	04 January 2018
		US	2018-0014128	A1	11 January 2018
		US	2018-0020291	A1	18 January 2018
		US	2018-0063652	A1	01 March 2018
		US	2018-0213331	A1	26 July 2018
		US	2018-0213335	A1	26 July 2018
		US	2018-0262846	A1	13 September 2018
		US	2019-0069097	A1	28 February 2019
		US	2019-0158961	A1	23 May 2019
		US	2020-0037082	A1	30 January 2020
		US	2020-0084551	A1	12 March 2020
		US	2020-0084553	A1	12 March 2020
		US	2021-0266686	A1	26 August 2021
		US	2021-0274293	A1	02 September 2021
		US	2021-0306777	A1	30 September 2021
		US	2022-0007114	A1	06 January 2022
		US	2022-0007115	A1	06 January 2022
		US	7421087	B2	02 September 2008
		US	7668325	B2	23 February 2010
		US	7867160	B2	11 January 2011
		US	7955249	B2	07 June 2011
		US	8295523	B2	23 October 2012
		US	8396239	B2	12 March 2013
		US	8401212	B2	19 March 2013
		US	8696541	B2	15 April 2014
		US	8715152	B2	06 May 2014
		US	8824715	B2	02 September 2014
		US	8858419	B2	14 October 2014
		US	9049528	B2	02 June 2015

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IB2024/055512

Patent document cited in search report			Publication date (day/month/year)	Patent family member(s)			Publication date (day/month/year)
				US	9154891	B2	06 October 2015
				US	9226083	B2	29 December 2015
				US	9591409	B2	07 March 2017
				US	9749758	B2	29 August 2017
				US	9949035	B2	17 April 2018
				US	9949039	B2	17 April 2018
				US	9961454	B2	01 May 2018
				WO	2006-014915	A2	09 February 2006
				WO	2006-014915	A3	26 May 2006
				WO	2006-042298	A2	20 April 2006
				WO	2006-042298	A3	28 December 2006
				WO	2006-042298	A9	12 October 2006
				WO	2006-118819	A2	09 November 2006
				WO	2006-118819	A3	13 December 2007
				WO	2007-053653	A2	10 May 2007
				WO	2007-053653	A3	29 November 2007
				WO	2009-046329	A1	09 April 2009
				WO	2009-049320	A1	16 April 2009
				WO	2009-155358	A1	23 December 2009
				WO	2009-155361	A1	23 December 2009
				WO	2010-033932	A1	25 March 2010
				WO	2010-033933	A1	25 March 2010
WO	2010-142018	A1	16 December 2010	AU	2010-258035	A1	12 January 2012
				AU	258035	B2	04 December 2014
				AU	258035	B9	16 July 2015
				CA	2764763	A1	16 December 2010
				CA	2764763	C	11 August 2015
				CN	102458323	A	16 May 2012
				CN	102458323	B	06 May 2015
				EP	2440166	A1	18 April 2012
				EP	2440166	A4	21 November 2012
				EP	2440166	B1	14 December 2016
				US	2012-0088957	A1	12 April 2012
				US	8942400	B2	27 January 2015
				WO	2010-142018	A8	19 May 2011
US	10477332	B2	12 November 2019	US	2018-020301	A1	18 January 2018
US	2007-0156011	A1	05 July 2007	AU	2006-333402	A1	12 July 2007
				AU	2006-333402	B2	19 August 2010
				CN	101422051	A	29 April 2009
				CN	101422051	B	04 July 2012
				DK	1972179	T3	09 February 2015
				EP	1972179	A2	24 September 2008
				EP	1972179	B1	12 November 2014
				US	7670278	B2	02 March 2010
				WO	2007-078506	A2	12 July 2007
				WO	2007-078506	A3	24 December 2008