

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

UTILITY APPLICATION FOR UNITED STATES PATENT

FOR

Fully-Implantable Cochlear Implant with Nasal Insertion Capability

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Fully-Implantable Cochlear Implant with Nasal Insertion Capability

FIELD OF THE INVENTION

5 The invention generally relates to cochlear implants and, more particularly, the invention relates to nasally-insertable, fully-implantable cochlear implants.

BACKGROUND OF THE INVENTION

10 Cochlear implants may provide a person having sensorineural hearing loss with the ability to perceive sound by stimulating the person's auditory nerve via an array (or other configuration) of electrodes implanted in the person's cochlea. Typically, the cochlear implant functions to detect sound waves, convert
15 the sound waves into a series of electrical stimulation signals, and deliver the stimulation signals to the cochlear implant recipient's auditory nerve via the array of electrodes. Stimulating the auditory nerve in this manner may enable the cochlear implant recipient's brain to perceive a hearing sensation that is similar to the natural hearing sensation delivered to a properly functioning auditory
20 nerve.

 Cochlear implants typically consist of two key components, namely an external component and an internal component. The external and internal components operate together to deliver the hearing sensation to the cochlear
25 implant recipient.

 The external component typically includes a microphone that detects sounds, such as speech and other environmental sounds, a sound processor that converts sounds detected by the microphone into a coded signal, a power source
30 such as a battery, and an external transmitter unit. The internal component typically includes an internal receiver unit as well as a stimulator.

In operation, the external transmitter unit and the internal receiver unit may be positioned relative to one another so as to be inductively coupled. In this manner, data and power may be communicated transcutaneously from the external component to the internal component. This communication serves two essential purposes. First, the communication serves to transcutaneously transmit the coded sound signal output by the sound processor to the internal component and, second, the communication serves to provide power from the power source to the internal component. Conventionally, this link has been in the form of a radio frequency (RF) link, but other such links could also be implemented.

Once the coded signal is received by the internal component, the stimulator outputs a stimulation signal based on the coded signal to an array of electrodes implanted in the cochlea, and the array of electrodes applies the electrical stimulation to the auditory nerve of the cochlear implant recipient. The application of the electrical stimulation to the auditory nerve produces a hearing sensation that at least partially corresponds to the original detected sound.

The external component of the cochlear implant is typically carried on the body of the cochlear implant recipient, such as in a small unit worn behind the ear. While these so-called behind-the-ear (BTE) units are an improvement over previous cochlear implants, most cochlear implants still require an external transmitter unit to be positioned on the side of the cochlear implant recipient's head to allow for the transmission of the coded signal from the speech processor, and power from the power source, to the internal component.

The internal component of the cochlear implant requires surgical installation. An incision is made behind the ear, a recess is routed in the surface of the skull, and a fine procedure with potential side effects is required to open the round window. The incision must heal and the swelling must subside before the external component of the cochlear implant can be fitted. This generally

means between two and four weeks with no auditory stimulation, unless the opposite ear provides sufficient hearing.

The external component of the cochlear implant is a source of
5 inconvenience and discomfort for many cochlear implant recipients. For
example, cochlear implant recipients cannot wear the devices while showering or
engaging in water-related activities. Most cochlear implant recipients also do not
use the devices while sleeping due to discomfort caused by the presence of the
BTE unit or the external transmitter unit and the likelihood that the alignment
10 between the external transmitter unit and the internal receiver unit will be lost
due to movements during sleep. For these and other reasons, there exists a need
for a cochlear implant that allows for improved freedom, simplicity, and
reliability.

15 One attractive option for meeting this need is a fully-implantable cochlear
implant that allows the microphone, the power source, and the speech processor
of the external component to be implanted in the cochlear implant recipient
along with the internal component.

20 Generally, however, fully-implantable cochlear implants complicate the
surgical procedure for implanting the cochlear implant by increasing the number
of components that need to be implanted. Additionally, the increased length of
the surgical procedure may increase the patient's risk of infection, as well as
increase the costs of the surgery.

25 Thus, while fully-implantable cochlear implants are an improvement over
typical cochlear implants in terms of a user's freedom and comfort, the added
surgical complications may prevent fully-implantable cochlear implants from
becoming a viable alternative to typical cochlear implants having one or more
30 external components.

SUMMARY OF VARIOUS EMBODIMENTS

In accordance with one aspect of the invention, a fully-implantable cochlear implant is surgically inserted through the nasal passage. Ancillary surgical tools including conventional arthroscopic instruments may be inserted
5 through the opposite nasal passage and the tympanic membrane.

In accordance with another aspect of the invention, the fully-implantable cochlear implant may be manufactured on a flexible substrate capable of being rolled into a sufficiently small diameter. One aspect of the invention allows for
10 the implant to be deployed by unfurling in the frontal sinus or the maxillary sinus.

A third aspect of the invention is the use of a low-power beam-formed radio frequency power source to charge an on-board supercapacitor or other
15 high-density energy storage device. The beam-formed aspect of the charger facilitates automatic charging of the internal energy storage device while the user is asleep. This wireless charging technology complements the low user maintenance paradigm of the fully-implantable cochlear implant.

20 BRIEF DESCRIPTION OF THE DRAWINGS

Those skilled in the art should more fully appreciate advantages of various embodiments of the invention from the following "Description of Illustrative Embodiments," discussed with reference to the drawings summarized immediately below.

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Figure 1 shows an example of a cochlear implant.

Figure 2 shows example internal components of a typical non-fully-implantable cochlear implants.

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Figure 3 shows a fully-implantable cochlear implant with nasal insertion capability.

5 Figure 4 shows an example of a fully-implantable cochlear implant in the surgical insertion configuration.

Figure 5 shows an example of a fully-implantable cochlear implant deployed in the frontal sinus.

10 Figure 6 shows an example of a beam-formed radio frequency power source preferentially charging the internal energy storage component of a fully-implantable cochlear implant.

What is claimed is:

1. An implantable device, comprising: a stimulator configured to generate a stimulation current comprising at least one stimulus; one or more leads to
5 conduct the stimulation current; a radio transceiver system including an antenna and associated circuitry to receive power and data, and to transmit data; a high-density energy storage device; and a flexible substrate.
- 10 2. The implantable device of claim 1, where the high-density energy storage device is a supercapacitor.
3. The implantable device of claim 1, where the one or more leads form an electrode array.
- 15 4. The implantable device of claim 3, where the electrode array may be inserted through the nasal passage, thence through the Eustachian tube, and terminating in the cochlea.
- 20 5. The implantable device of claim 4, where the electrode array is functionally connected to the stimulator.
6. The implantable device of claim 5, where the stimulator is mounted on the flexible substrate.
- 25 7. The implantable device of claim 6, where the flexible substrate also contains the radio-frequency interface components and the high-density energy storage device.
- 30 8. An implantable device, comprising a receiving antenna, circuitry to interface with said antenna, and a high-density energy storage device.

9. The implantable device of claim 8, where the receiving antenna is flexible.

5 10. The implantable device of claim 9, where the flexible receiving antenna is mounted on a flexible substrate.

11. The implantable device of claim 10, where the receiving antenna receives power and stores it in a high-density energy storage device.

10 12. A cochlear implant, comprising: a stimulator configured to generate a stimulation current comprising at least one stimulus; one or more leads to conduct the stimulation current; a radio transceiver system including an antenna and associated circuitry to receive power and data, and to transmit data; a high-density energy storage device; and a flexible
15 substrate.

13. The cochlear implant of claim 12, where the cochlear implant is inserted through the nasal passage, thence through the Eustachian tube, and terminating in the cochlea.

20 14. The cochlear implant of claim 13, where the flexible substrate is unfurled after insertion, and lies substantially flat in a sinus cavity.

25 15. The cochlear implant of claim 14, where the power is derived from a focused radio-frequency beam applied for a portion of the day.

16. The cochlear implant of claim 15, where the high-density energy storage device can store sufficient energy to power the cochlear implant for at least a day.

17. The cochlear implant of claim 16, where the high-density energy storage device is a supercapacitor.
- 5 18. The cochlear implant of claim 17, where the normal operation of the implant is powered by the supercapacitor.

ABSTRACT OF THE DISCLOSURE

A fully-implantable cochlear implant system with nasal insertion capability. The flexible substrate of the electronics allows furling into a cylindrical shape for nasal insertion, followed by unfurling in the sinus cavity. Arthroscopic surgical
5 instruments may be inserted through the opposite nostril and through an incision in the tympanic membrane. Rapid patient recovery enables activation within hours of the surgery. Wireless charging is afforded by a bed-side charger.