LEAD CONNECTION MODULE OF A MODULAR IMPLANTABLE MEDICAL DEVICE

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ABSTRACT

A modular implantable medical device includes two or more interconnected modules and an overmold that at least partially encapsulates each of the housings of the modules. The overmold also includes a lead connection module for accepting an external lead. The lead connection module electrically and mechanically couples the lead to the components of the implantable medical device.
LEAD CONNECTION MODULE OF A MODULAR IMPLANTABLE MEDICAL DEVICE

[0001] This application claims the benefit of:


[0005] 4. U.S. Provisional Application entitled "Implantable CRANIAL MEDICAL DEVICES AND METHODS," Ser. No. 60/503,946, (Attorney Docket No. P-11697.00), filed on Sep. 20, 2003; and


[0007] The following co-pending and commonly-assigned U.S. Patent Applications, filed on even date herewith, are also incorporated herein by reference in their entirety:


TECHNICAL FIELD

[0016] The invention relates to medical devices, and more particularly, to implantable medical devices that deliver therapy to and/or monitor a patient.

BACKGROUND

[0017] Depending on the application for which they are implanted in a patient, implantable medical devices (IMDs) may include a variety of electrical and/or mechanical components. Typically, an IMD includes a rigid housing that houses all of its components, which are generally fragile, to protect the components from forces to which they would otherwise be exposed when implanted within the human body. In order to avoid potentially harmful interactions between the components and bodily fluids, e.g., corrosion, IMD housings are typically hermetically sealed. Many IMD housings are fabricated from Titanium because of its desirable rigidity and biocompatibility.

[0018] The size and shape of an IMD housing is dependent on the sizes and shapes of the components of the IMD. Large components common to most IMDs include a battery, a telemetry coil, and a hybrid circuit that includes digital circuits, e.g., integrated circuit chips and/or a microprocessor, and analog circuit components. Attempts have been made to reduce the size of the IMD housing by reducing the size of these components, changing the shape of these components, and organizing these components within the IMD housing to avoid empty space within the housing. Despite these efforts to reduce the size of IMD housings, the size, shape and rigidity of IMD housings still greatly limits the locations within the human body where an IMD can be practically implanted.

[0019] Due to these limitations, an IMD is typically implanted within the abdomen, upper pectoral region, or interclavicular region of a patient. Leads or catheters must be used in order to deliver therapy or monitor a physiological parameter at a location of the body other than where the IMD is implanted. Implantation and positioning of leads and catheters can be difficult and time-consuming from the perspective of a surgeon, particularly where the IMD is located a significant distance from the treatment or monitoring site. Moreover, the increased surgical time, increased surgical trauma, and increased amount of implanted material associated with the use of leads and catheters can increase the risk to the patient of complications associated with the implantation of an IMD.

[0020] For example, IMDs that are used to treat or monitor the brain, e.g., to deliver deep brain stimulation (DBS)
therapy, are implanted some distance away from the brain, e.g., within the interclavicular region of patients. The long leads that connect the implantable medical device to electrodes implanted within the brain require tunneling under the scalp and the skin of the neck, thereby requiring increased surgery and a prolonged amount of time under general anesthesia during the implant procedure. The lengthy tract along the leads is more susceptible to infection, and the leads can erode the overlying scalp, forcing removal so that the scalp can heal. Further, the long leads running under the scalp and through the neck are more susceptible to fracture due to torsional and other forces caused by normal head and neck movements.

SUMMARY

[0021] In general, the invention relates to a lead connection module of a modular implantable medical device. In order to provide an implantable medical device with a smaller profile so that the IMD can better fit into available body locations, various functional components of the IMD are separated into individual interconnected modules. This modular architecture for the implantable medical device permits the device footprint to be distributed over a larger area while making the profile smaller. In addition, the multiple modules and their respective flexible interconnections may permit the overall shape of the implantable medical device to be formed to better match the body location into which it is to be implanted.

[0022] In a typical application, the component modules within the IMD are coupled to one or more leads that are deployed within a patient's body. External leads are used to electrically connect the external locations to a control module within the implantable medical device, and the control module can monitor the electrical activity, or regulate administration of therapy, or both. Accordingly, it is desirable for the external leads be both electronically and mechanically coupled to the implantable medical device. The present invention provides such a coupling of the external leads to the implantable medical device.

[0023] In one embodiment, the invention is directed to an implantable medical device that includes at least two interconnected modules, each of the modules comprising a housing, and an overmold that at least partially encapsulates each of the housings. The overmold comprises a lead connection module that is configured to accept an external lead. In some variations, the invention supports an overmold made of multiple materials, such as elastomeric and non-elastomeric materials.

[0024] In another embodiment, the invention is directed to an overmold for a modular implantable medical device. The overmold comprises a first material configured to hold at least part of a module, a second material coupled to the first material, and a lead connection module configured to accept an external lead, the lead connection module being deployed within the overmold.

[0025] The details of one or more embodiments of the invention are set forth in the accompanying drawings and the description below. Other features, objects, and advantages of the invention will be apparent from the description and drawings, and from the claims.

BRIEF DESCRIPTION OF DRAWINGS

[0026] FIGS. 1A and 1B are diagrams illustrating use of an implantable medical device in a patient according to an example embodiment of the present invention.

[0027] FIG. 2 is a schematic diagram illustrating an implantable medical device according to an embodiment of the present invention.

[0028] FIG. 3A and 3B are schematic diagrams illustrating an implantable medical device according to another embodiment of the present invention.

[0029] FIGS. 4A-4F are schematic diagrams illustrating various orientations of multiple modules within an implantable medical device according to various embodiments of the present invention.

[0030] FIG. 5A is a schematic diagram illustrating the construction of an overmold and modules used in construction of an implantable medical device according to the present invention.

[0031] FIG. 5B is an exploded view of an embodiment of the overmold and modules shown in FIG. 5A.

[0032] FIG. 5C is a side view of an embodiment of the overmold and modules shown in FIG. 5A.

[0033] FIGS. 6A-6J are schematic diagrams illustrating an example embodiment of a multi-module implantable medical device having multiple interconnect sites according to the present invention.

[0034] FIGS. 7A-7B are schematic diagrams illustrating an example embodiment of a multi-module implantable medical device having tethered interconnect sites according to the present invention.

[0035] FIG. 7C is a perspective view of a multi-module implantable medical device such as that depicted in FIGS. 7A and 7B.

[0036] FIGS. 8A-8J are schematic diagrams illustrating the interaction of components of an implantable medical device that are part of an overmold according to the present invention.

[0037] FIGS. 9A-9B are schematic diagrams illustrating an electronic module of a multi-module implantable medical device having a connection leads according to the present invention.

DETAILED DESCRIPTION

[0038] FIGS. 1A and 1B are diagrams illustrating use of an implantable medical device (IMD) in a patient according to an example embodiment of the present invention. An IMD 101 is implanted within a patient 100 in order to permit IMD 101 to provide therapies to the patient 100. In the example illustrated within FIGS. 1A-1B, IMD 101 is implanted under the scalp of the patient 100 in order to locate the device 101 as close as possible to the location of leads 102 that provide the therapy.

[0039] FIG. 1A shows patient 100 with IMD 101 deployed beneath his scalp. In FIG. 1A, IMD 101 is a neurostimulator that provides deep brain stimulation via leads 102 deployed in the brain of patient 100. IMD 101 is deployed in proximity to site of stimulation therapy. IMD
101 may be used to treat any nervous system disorder including, but not limited to, epilepsy, pain, psychological disorders including mood and anxiety disorders, movement disorders (MVD) such as, but not limited to, essential tremor and Parkinson's disease and neurodegenerative disorders.

Although IMD 101 is described as a neurostimulator, the invention is not limited to applications in which the IMD is a neurostimulator. The invention may be employed with IMDS that perform any monitoring or therapeutic functions. The invention is not limited to IMDS that include leads deployed in the brain, but may also be employed with leads deployed anywhere in the head or neck including, for example, leads deployed on or near the surface of the skull, leads deployed beneath the skull such as near or on the dura mater, leads placed adjacent cranial or other nerves in the neck or head, or leads placed directly on the surface of the brain. Nor is the invention limited to IMDS that are coupled to electrodes. The invention may be employed with IMDS coupled to any sensing or therapeutic elements, such as temperature sensors or motion sensors. The invention may also be employed with different types of IMDS including, but not limited to, IMDS operating in an open loop mode (also referred to as non-responsive operation), IMDS operating in a closed loop mode (also referred to as responsive), and IMDS for providing monitoring and/or warning.

In general, IMD 101 has a low profile, i.e., IMD 101 is thin to permit the IMD 101 to be deployed effectively, comfortably and cosmetically and under the scalp. In one embodiment of the invention, IMD 101 has a maximum thickness of between approximately 4 millimeters and approximately 8 millimeters. The use of a reduced profile may reduce the risk of infection, skin erosion and cosmetic issues related to the implantation of IMD 101.

Many locations within a patient do not present adequate profile for implantable medical devices. As such, many uses of such devices employ lengthy leads located remote from an implantation site of the IMD. The use of these lengthy leads requires complicated insertion procedures from the site of the IMD to the site of lead deployment that may cause medical complications to the patient as well as may lead to failures in connection leads. By constructing IMD 101 as a set of distributed modules connected together as described herein, IMD 101 may be deployed proximate to a treatment or monitoring site.

While the embodiment of IMD 101 shown in FIGS. 1A-1B is implanted under the scalp of patient 100 and may be used when the therapy provided to patient 100 includes neural stimulation of a brain, other embodiments of IMD 100 permit the device to be implanted at many other locations within the body. In addition, IMD 101 includes a plurality of interconnected modules. Each module generally perform assigned functions.

In the typical embodiment depicted in FIG. 1B, IMD 101 includes three modules, namely, a control module 103, a power supply module 104 and a recharge module 105. Control module 103 typically includes the electronic components associated with the functions of IMD 101. In a typical implementation, control module 103 may include a hybrid circuit that includes digital circuits such as integrated circuit chips and one or more microprocessors, and analog circuit components. Accordingly, control module 103 may also be referred to as an electronic module. Power supply module 104 typically comprises one or more energy storage devices, such as a rechargeable lithium ion battery. Recharge module 105 typically includes one or more coils for transmitting or receiving electromagnetic energy through the scalp. The transmitted energy may include energy to be stored in power supply module 104. In some embodiments, the transmitted energy may also include communication, such as information encoded in radio frequency transmissions.

Individual modules 103 and 104 may be encased in biocompatible material such as titanium shield halve, and may be sealed against contamination. In addition, individual modules 103 and 104 may include insulation to electrically isolate the electrical components inside the modules from the metal shields. The modules are coupled to an overmold 106 which may be made of a biocompatible material. Use of the term “overmold” herein is not intend to limit the invention to embodiments in which the overmold is molded structure. Overmold may be a molded structure, or may be a structure formed by any process.

In some embodiments of the invention, overmold 106 encases all modules 103, 104 and 105. In other embodiments, overmold 106 is disposed over or around the modules without encasing the modules. In further embodiments, overmold 106 acts as a “frame” to hold the modules in a fixed position relative to one another, but does not fully cover the modules. Some features of the overmold, and variations on the shape of the overmold, are presented below. In general, the shape of the overmold depends upon the arrangement of the modules. The overmold may be made of a variety of materials, such as flexible silicone. The overmold may also include a rigid polymer such as Ticona surrounded by flexible silicone. The invention is not limited to these materials, however, and the overmold may comprise any combination of elastomeric and/or non-elastomeric materials.

FIG. 2 is a schematic diagram illustrating an IMD according to another embodiment of the present invention. In this example embodiment, the IMD 201 is arranged in a triangular configuration, and includes three modules: a control module 210, a power supply module 211, and a recharge module 212. Overmold 214 at least partially covers the housings of control module 210 and power source supply module 211, and also at least partially covers recharge module 212. These three modules are physically connected together to construct IMD 201, and any modules may also be electrically coupled to one another.

IMD 201 also includes two lead connection modules 213A, 213B for accepting an external lead. In particular, overmold 214 includes lead connection modules 213A, 213B, and lead connection modules 213A, 213B need not be fixedly coupled to any modules 210, 211 or 212. Lead connection modules 213A, 213B contain a set of lead connection modules that permits external leads to be connected to the IMD 210. In the case of electronic leads, for example, lead connection modules 213A, 213B include one or more conductors that electrically couple the external leads to control module 210. The triangular configuration of IMD 201 permits IMD 201 to possess a thin profile by spreading the modules over a larger surface area. The triangular shape also helps to keep the surface area compact. The structure of IMD 201 may also be curved to conform to the shape of the
location within a patient in which the device is being implanted. For example, implantation of IMD 201 under the scalp of a patient may be accomplished if the overall shape of IMD 201 is curved to follow the shape of a patient’s skull. Any number of shapes may be used to match a particular IMD 201 to an implantation location for a device.

[0049] FIGS. 3A and 3B are schematic diagrams illustrating an IMD according to yet another embodiment of the present invention. In this embodiment of IMD 301, a flat device is shown that consists of multiple modules. This embodiment of IMD 310 may be used in other locations within a patient in which the implantation location does not require such an exact match between the device and physical structures of the patient such as bone or muscle. IMD 301 may provide a small profile when implanted as to not protrude excessively once implanted.

[0050] The flat embodiment shown in FIGS. 3A-3B may represent a device that may be a pectoral implant that may be used to treat angina, to provide vagal nerve stimulation, or to provide cardiac rhythm management. Similar devices may be implanted into an upper buttock implant location, into an abdomen location, and into periphery. A device implanted into an upper buttock location may be useful in urological and gastroenterological implantation therapies. A device implanted into an abdomen location may be useful in providing pain, spasticity, and chemotherapy treatments. A device implanted into a periphery location may be useful in providing muscle stimulation, on-site nerve stimulation, and diaphragm stimulation therapies.

[0051] IMD 301 comprises an overmold 302 that includes two lead connection modules 303A, 303B for accepting an external lead. In FIGS. 3A and 3B, lead connection modules 303A, 303B are depicted open to illustrate inclusion in overmold 302.

[0052] Additional alternate embodiments for implantable medical devices implemented according to principles of the present invention may also include nonelectrical based therapies such as targeted introduction of fluids and similar therapeutic materials using pumps and reservoirs of material. One skilled in the art will recognize that any number of implantable devices may be possible without deviating from the spirit and scope of the present invention as recited within the attached claims.

[0053] FIGS. 4A-4F are schematic diagrams illustrating exemplary configurations and orientations of modules within IMD 401 through 401F (hereinafter 410), according to various embodiments of the present invention. IMD 401 consists of multiple modules that may be arranged into any number of orientations as shown in the various embodiments of FIGS. 4A-4F. For reference, each IMD 401 is depicted deployed proximate to the skull of a patient, with leads 402A and 402B deployed through burr holes 402A and 402B and coupled to IMD 401. The leads are coupled to the IMD via lead connection modules 415A and 415B. As shown in FIGS. 4A-4F, the lead connection modules may assume a variety of orientations relative to the 401 components of IMD 401.

[0054] In each of these embodiments, IMD 401 has three modules as discussed above in reference to FIGS. 1B and 2: a control module 410, a power source module 411, and a recharge module 412. An overmold 413 at least partially covers the housings of control module 410 and power source module 411. The modules may be arranged into a number of orientations as long as any interconnections between the modules may be routed within the device. The various embodiments include triangular configurations, as is shown in FIGS. 4A-4C, or linear configurations as shown in FIGS. 4D-4F. In FIG. 4D, one of the three modules, such as the recharge module, is deployed as a tethered module 414 rather than being covered by overmold 413.

[0055] The invention is not limited to the deployments of the lead connection modules shown in FIGS. 4A-4F. The lead connection modules may be located on various positions within IMD 401. Lead connection modules may be oriented, for example, to permit the leads to be routed to lead locations in an efficient manner or to support management of excess lead length. Any number of other orientations and alternate embodiments may be constructed according to principles of the present invention and consistent with the claims recited herein.

[0056] FIGS. 5A-5C are schematic diagrams illustrating an exemplary construction of an overmold used in construction of an IMD according to the present invention. FIG. 5A illustrates that IMD 501 comprises a set of modules 510-512, a set of motion restriction elements, such as motion restriction fibers 521. In FIG. 5A, motion restriction fibers 521 are coupled to modules 510 and 511, and are covered at least in part by overmold 522. Overmold 522 typically includes a solid biocompatible material. Overmold 522 may comprise an elastomeric material that is soft and flexible, such as silicone. In addition or in the alternative, overmold 522 may comprise a non-elastomeric material that imparts rigidity to IMD 501. In one embodiment, for example, a non-elastomeric material in overmold 522 acts as a “frame” to hold the modules in a fixed position relative to one another, and does not fully cover the modules. Overmold 522 covers, at least in part, the components and modules within IMD 501 while providing a flexible structure that permits the device 501 to conform to fit each individual patient. Because overmold 522 is typically flexible, IMD 501 may benefit from motion restriction devices such as motion restriction fibers 521, which provide structural integrity to device 501 once implanted into the patient.


[0058] FIG. 5B illustrates that the overmold 522 may include a non-elastomeric, or “hard” component 531 in addition to an elastomeric, or “soft” component 532. In FIG. 5B, the non-elastomeric component 531 is shaped to conform to the shape of at least one of modules 510-512 such that the modules may be restrained from motion by the non-elastomeric components. The non-elastomeric components 531 are typically made of a solid biocompatible material such as polysulfone, and may also be made of metal such as titanium.

[0059] The non-elastomeric components 531 are utilized in locations in which motion is to be restricted. Any or all modules may be constrained by one or more hard compo-
nents 531. Overmold 522, including elastomeric and non-

elastomeric components, can be fabricated into a single

structure before the modules 510-512 are inserted into the
device 501.

[0060] Generally, overmold 522 serves a number of func-
tions. For example, overmold 522 incorporates motion

restriction elements within the device 501, and attaches to
modules and other elements to provide a unified device. In
addition, overmold 522 provides a smooth interface sur-
face for the device as it interacts with the patient, and protects
electrical connections and feed through wires that connect
modules to external leads.

[0061] Overmold 522 may also include a diurometric

specific material to provide desired device qualities such as
flexibility and structural integrity. In addition, the material
used to construct overmold 522 may possess a thermal

conductivity characteristic to either act as a heat sink, or act
as an insulator to shield the patient 100 from any excess heat
from IMD 501. Because IMD 501 may be constructed from

a large number of modules to perform a desired task, the
materials selected for use in constructing the overmold 522
may vary as needed by each embodiment.

[0062] FIG. 5C illustrates that overmold 522 provides

sloped interface 541 between an exemplary module 542
within IMD 501 and the patient’s body. In embodiments in
which IMD 501 is implanted within tight spaces, such as
under the scalp of the patient, sloped interface 541 provides
a smooth transition and eases sharp edges that are known to
cause possible points of stress for tissue. An angle of

interface from the patient’s body and the sloped interface
541 can be approximately 135 degrees.

[0063] Additional details regarding the overmold 522

are described in co-pending and commonly assigned U.S. Patent
Application entitled “OVERMOLD FOR A MODULAR

IMPLANTABLE MEDICAL DEVICE,” assigned Attorney
Docket No.: 1023-332USO1/P-11798.00.

[0064] FIGS. 6A-6B are schematic diagrams illustrating

an example embodiment of a multi-module IMD 601 having
multiple interconnect sites according to the present inven-
tion. FIG. 6A shows a distributed IMD have multiple lead
connection modules 613 that are located adjacent to each
other while being near a control module 610. In contrast,
FIG. 6B shows a distributed IMD have multiple lead
connection modules 613 that are located on opposite sides of
the control module 610. In FIGS. 6A and 6B, lead connec-
tion modules are included in overmold 622. The lead con-
nection modules 613 provide a mechanism for electrically
connecting electronics within control module 610 to one or
more external leads 643. The external leads provide an
electrical signal path from a desired part of the patient’s
body to IMD 601.

[0065] The embodiment shown is FIG. 6A is used when
it is desirable for the external leads 643 to follow similar
signal path lengths from the control module 610 to the


treatment or monitoring site of the body. The embodiment of
FIG. 6B may be used in cases in which the external leads
643 are farther apart. Because the lead connection modules
613 provide electrical connections between the control mod-
ule 610 and the external leads 643, the lead connection
modules 613 are typically located close to the control
module 610 to reduce a length for electrical interconnections
between them. Additional details regarding the interconnec-
tion of the control module 610, the lead connection modules
613, and the external leads 643 is discussed below in refer-
cence to FIGS. 8A-8B.

[0066] FIGS. 7A-7B are schematic diagrams illustrating

an example embodiment of a multi-module IMD having
tethered interconnect sites according to the present inven-
tion. In a first embodiment shown in FIG. 7A, an overmold
722 of an IMD 701 may cover and connect a plurality of
modules 710-712 while not covering lead connection mod-
ules 713, which are part of a tethered interconnection
housing 761. As shown in FIG. 7B, tethered interconnection
housing 761 is optional.

[0067] In these embodiments, the lead connection
modules 713 that are used to connect external leads (not shown)
to the device 701 are not contained within the overmold 722.
As such, the implantation of the device would not require the
insertion of external leads into the 722. In addition, the
external leads may be located a distance away from the
overall device 701. Such an arrangement may assist in the
management of the external leads as they are placed within
the patient and routed to a lead location.

[0068] In an alternate embodiment shown in FIG. 7C,
overmold 722 may include mechanical structures such one
or more grooves or a pouch to contain and route the external
leads and aid lead management. An exemplary structure, a
groove 750, is depicted in a perspective view of IMD 701.
In some implantations, external leads may possess an excess
length that may be managed to reduce the risks of lead
migration and lead damage.

[0069] FIGS. 8A-8B are schematic diagrams illustrating

an exemplary interaction of components of an IMD 801.
FIG. 8A provides a side view of an overmold 822, which
includes one or more soft or elastomeric components 832
and one or more hard or non-elastomeric components 831,
which interface with a control module 810. Non-elastomeric
component 831 may be shaped to mate with the module 810
to provide motion restriction for the module. Non-elastom-
eric component 831 may be mechanically connected to
other modules using a motion restriction device (not shown).
The overmold 822 covers all of these components in this
embodiment. A through hole 851 may be located through the
non-elastomeric component 831 and elastomeric component
832 to provide an attachment point for IMD 801. In some
embodiments, IMD 801 may be anchored in place using
bone screws or other anchoring devices. Through holes 851
permit IMD 801 to be mechanically anchored to the patient
once the device 801 is positioned at a desired location. In
the embodiment shown in FIG. 8A, a bone screw inserted into
through hole 851 would seat against non-elastomeric com-
ponent 831, but the invention encompasses embodiments in
which a bone screw would seat against another component,
such as control module 810.

[0070] FIG. 8B illustrates a top view of the device 801
having elastomeric component 832 of overmold 822 covering
the non-elastomeric components 831 that frame control
module 810. The through hole 851 used as an attachment
point is shown as part of non-elastomeric component 831
that is covered by elastomeric component 832. The shape of
non-elastomeric component 831 and control module 810 are
shown as being rectangular in this embodiment. However,
one skilled in the art will recognize that any shape for the
non-elastomeric component 831 and control module 810 may be used without deviating from the spirit and scope of the present invention.

In both FIG. 8A and 8B, a lead interconnect device 813 is included within the non-elastomeric components 831 of overmold 822. In these examples, the non-elastomeric component 831 restrains control module 810 and external leads 843. Typically, the external leads have iso-diametric proximal ends for connection of the external leads 843 to IMD 801. An external lead 843 is inserted into the lead connection module in order to connect the leads 843 to electronics within control module 810 of IMD 801. This electrical connection from the control module 810 to the external leads 843 is made using a module connection lead wire 846 that extends from control module 810 and physically connects with the external lead 843 within the lead connection module 813.

The lead connection module 813 may also include a mechanical lead securing mechanism 845 that engages the external lead 843 to restrain its motion and ensure electrical connection with feed-through wires 846. In the embodiment of FIG. 8A, a tool 847 is used to engage the mechanical lead securing mechanism 845 within the lead connection module 813. In this embodiment, the mechanical lead securing mechanism 845 comprises a mechanical set-screw that is tightened by a screwdriver. An example of such a mechanical lead securing mechanism 845 is a low-profile DBS lead extensions manufactured by Medtronic Inc. In alternate embodiments, the mechanical lead securing mechanism 845 may be tool-less using a variety of known securing technologies that ensures the external lead 843 does not separate from the lead connection module 813. Tool-assisted or tool-less coupling of leads to the IMD both allow medical personnel to couple leads to the IMD quickly and securely.

FIGS. 9A-9B are schematic diagrams illustrating a control module of a multi-module IMD having a connection leads according to the present invention. FIG. 9A provides a perspective view of a control module 910 to illustrate a set of feed-through wires 946 that electrically couple electronics 950 within the control module 810 to external leads as discussed above in reference to FIGS. 8A and 8B. Similarly, FIG. 9B provides a side view of the control module 910 of FIG. 9A to again illustrate the use of the feed-through wires 946 as discussed above.

While the above embodiments of the present invention describe a lead interconnect module of a modular implantable medical device, one skilled in the art will recognize that the use of a module structure are merely exemplary embodiments of the present invention. It is to be understood that other embodiments may be utilized and operational changes may be made without departing from the scope of the present invention as recited in the attached claims.

As such, the foregoing description of the exemplary embodiments of the invention has been presented for the purposes of illustration and description. They are not intended to be exhaustive or to limit the invention to the precise forms disclosed. Many modifications and variations are possible in light of the above teaching. It is intended that the scope of the invention be limited not with this detailed description, but rather by the claims appended hereto. The present invention is presently embodied as a lead interconnect module of a modular implantable medical device.

What is claimed is:

1. An implantable medical device comprising:
   at least two interconnected modules, each of the modules comprising a housing; and
   an overmold that at least partially encapsulates each of the housings, the overmold comprising a lead connection module for accepting an external lead.

2. The implantable medical device of claim 1, wherein at least one module comprises a control module containing electronic components.

3. The implantable medical device of claim 1, wherein the overmold comprises a first material and a second material, and the lead connection module is deployed within the first material.

4. The implantable medical device of claim 3, wherein the first material comprises a non-elastomeric material.

5. The implantable medical device of claim 1, the lead connection module comprising at least one feed-through wire to electrically couple an external lead to an electronic component within the implantable medical device.

6. The implantable medical device of claim 1, wherein the lead connection module includes a mechanical lead securing mechanism.

7. The implantable medical device of claim 6, wherein the mechanical lead securing mechanism comprises a tool-less mechanical lead securing mechanism.

8. The implantable medical device of claim 1, wherein the implantable medical device has a maximum thickness of between approximately 4 millimeters and approximately 8 millimeters.

9. An overmold for a modular implantable medical device comprising:
   a first material configured to hold at least part of a module; a second material coupled to the first material; and
   a lead connection module configured to accept an external lead, the lead connection module being deployed within the overmold.

10. The overmold of claim 9, wherein the first material comprises a non-elastomeric material.

11. The overmold of claim 9, wherein the second material comprises an elastomeric material.

12. The overmold of claim 9, wherein the second material comprises silicone.

13. The overmold of claim 9, wherein the lead connection module is deployed within the first material.

14. The overmold of claim 9, wherein the lead connection module is configured to receive an iso-diametric external lead.

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