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Inventor(s)	McCurry; Troy L. et al.

Electrolytic capacitor

Abstract

A capacitor is provided that includes a capacitor stack including an anode layer, cathode layer, and electrolytic layer electrically coupled together, the capacitor stack including a capacitor stack periphery. The capacitor also includes a first cover portion having a first cover portion periphery that aligns with the capacitor stack periphery, and a second cover portion having a second cover portion periphery that aligns with the capacitor stack periphery and received the first cover portion periphery to form a shell body for encasing the capacitor stack therein. The capacitor stack is isolated from the second cover portion to provide a neutrally charged second cover portion that is electrically coupled within an implanted medical device.

Inventors: **McCurry; Troy L. (West Union, SC), Hemphill; R. Jason (Sunset, SC), Sauls; Rodrick B. (Anderson, SC)**

Applicant: **Pacesetter, Inc.** (Sylmar, CA)

Family ID: **1000008763716**

Assignee: **Pacesetter, Inc. (Sylmar, CA)**

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Primary Examiner: Johnson; Nicole F

Attorney, Agent or Firm: The Small Patent Law Group, LLC

Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS (1) This application claims priority benefit to U.S. Provisional Application No. 63/167,427, which was filed on 29 Mar. 2021, and the disclosure of which is incorporated herein by reference in its entirety.

BACKGROUND
(1) Embodiments herein generally relate to electrolytic capacitors utilized for implanted medical devices (IMDs).
(2) High voltage capacitors are utilized as energy storage reservoirs in many applications, including IMDs. These capacitors are required to have a high energy density, to minimize the overall size of the implanted device. Such capacitors may be stacked electrolytic capacitors, typically constructed with a plurality of anodes and cathodes that separated by a liquid-absorbent insulating material that can be referred to as electrolytic paper. The electrolytic paper may be impregnated by an electrically conductive electrolyte.
(3) Improvement of the surface area creation per anode allows for the decrease of final volume of the capacitor to improve energy density through higher efficiency of packaging efficiency. However, the higher packaging efficiency needs to maintain lower tolerances on case/lid

configurations, boot geometries, and several design rule electrical standoff tolerances. The lower tolerances lead to higher cost for bill of materials (BOM) choices, lower reliability, and lower yield. Often thin pockets of poly(ether ether ketone) (PEEK) must be utilized for protection of the stacked electrolytic capacitor. Such protection requires precise manufacturing techniques, including complex manufacturing processes.

(4) In addition, the lower tolerances and thin PEEK pockets can lead to the capacitor being prone to cracking, decreasing the life of the capacitor. In addition, the out connection of the capacitor is a negative output resulting in decreased internal resistance within the capacitor that can result in increased capacitor temperatures, bubbling, and even failure.

(5) Further, for IMD application, because the IMD is subcutaneous, or under the skin of the patient, the size of the IMD must remain minimal. Meanwhile, the capacitor can represent the largest electrical component within the IMD. As a result, manufacturing constraints are also presented, preventing increases in tolerances or spatial changes to address cracking issues, internal capacitor resistances resulting in heat build-up and deformation, manufacturing complexities, or the like.

SUMMARY

(6) In accordance with embodiments herein, a capacitor is provided that includes a capacitor stack including an anode layer, cathode layer, and electrolytic layer electrically coupled together, the capacitor stack including a capacitor stack periphery. The capacitor also includes a first cover portion having a first cover portion periphery that aligns with the capacitor stack periphery, and a second cover portion having a second cover portion periphery that aligns with the capacitor stack periphery and received the first cover portion periphery to form a shell body for encasing the capacitor stack therein. The capacitor stack is isolated from the second cover portion to provide a neutrally charged second cover portion that is electrically coupled within an implanted medical device.

(7) Optionally, the first cover portion comprises an injection molded plastic. In one aspect the second cover portion is a metal case. In one aspect, the second cover portion comprises stainless steel. In another aspect, the capacitor stack includes an anode coupled to a first ferrule that extends through the shell body, and a cathode coupled to a second ferrule that extends through the shell body. In one example, the cathode includes a flat that that is welded to a wire assembly.

(8) In one embodiment, the capacitor stack periphery includes a front that arcuately transitions to an input side that includes a first portion and a second portion angled from the first portion, the input side arcuately transitions to a back that arcuately transitions into an arcuate side that arcuately transitions into the front. In another embodiment, the first cover periphery includes a front that arcuately transitions to an input side that includes a first portion and a second portion angled from the first portion, the input side arcuately transitions to a back that arcuately transitions into an arcuate side that arcuately transitions into the front of the first cover periphery, and the second cover periphery includes a front that arcuately transitions to an input side that includes a first portion and a second portion angled from the first portion, the input side arcuately transitions to a back that arcuately transitions into an arcuate side that arcuately transitions into the front of the second cover periphery.

(9) In accordance with embodiments herein, a method for manufacturing a capacitor for an implanted medical device is provided that includes forming a capacitor stack including an anode layer, cathode layer, and electrolytic layer that has a capacitor stack periphery. The method also includes forming a first cover portion having a first cover portion periphery that aligns with the capacitor stack periphery, and forming a second cover portion having a second cover portion periphery that aligns with the capacitor stack periphery. The method also includes disposing the capacitor stack within the first cover portion and second cover portion, forming an anode and cathode in the capacitor stack coupling a first ferrule to the cathode, and coupling a second ferrule to the anode.

(10) Optionally, forming the first cover portion comprises injection molding a plastic material to

form a boot. In one aspect, forming the second cover portion comprises stamping metal to form a case. In one example, the method also includes welding a wire assembly to a flat of the cathode. In another example, the method also includes adhering adhesive tape to the capacitor stack periphery. In one embodiment, the method additionally includes sealing an opening disposed through the first cover portion, and/or second cover portion with a ball element.

(11) In accordance with embodiments herein, a capacitor assembly is provided that includes a first capacitor having a first capacitor stack including an anode layer, cathode layer, and electrolytic layer electrically coupled together, the first capacitor stack including a first capacitor stack periphery. The first capacitor also includes a first shell body having a first cover portion with a first cover portion periphery that aligns with the first capacitor stack periphery, and a second cover portion having a second cover portion periphery that aligns with the first capacitor stack periphery and receives the first cover portion periphery for encasing the first capacitor stack therein. The capacitor assembly also includes a second capacitor that has a second capacitor stack including an anode layer, cathode layer, and electrolytic layer electrically coupled together, the second capacitor stack including a second capacitor stack periphery. The second capacitor also includes a second shell body stacked on the first shell body and has a first cover portion with a first cover portion periphery that aligns with the second capacitor stack periphery, and a second cover portion having a second cover portion periphery that aligns with the second capacitor stack periphery and received the first cover portion periphery for encasing the second capacitor stack therein. The capacitor assembly also includes a backing plate mechanically coupled to the first shell body and the second shell body and electrically coupled to an electronic coupler to provide an anode input and cathode input.

(12) Optionally, the electronic coupler includes at least one pin element. In one aspect, the second cover portion of the first shell body is neutrally charged, and the second cover portion of the second shell body is neutrally charged. In another aspect, the backing plate receives a first ferrule and second ferrule extending from the first shell body, and the backing plate receives a first ferrule and second ferrule extending from the second shell body. In one example, the first shell body has a first size and shape, and the second shell body has a second size and shape. The first size and shape are identical to the second size and shape. In yet another example, the electronic coupler is electrically coupled within an implanted medical device.

Description

DESCRIPTION OF THE DRAWINGS

(1) FIG. **1** illustrates a flow block diagram of a method for manufacturing a capacitor, in accordance with embodiments herein.

(2) FIG. **2** illustrates an exploded perspective view of a capacitor, in accordance with embodiments herein.

(3) FIG. **3** illustrates a cut away perspective view of a capacitor, in accordance with embodiments herein.

(4) FIG. **4** illustrates a perspective view of a capacitor, in accordance with embodiments herein.

(5) FIG. **5** illustrates an exploded perspective view of a capacitor, in accordance with embodiments herein.

(6) FIG. **6** illustrates a perspective view of a capacitor stack, in accordance with embodiments herein.

(7) FIG. **7** illustrates a cut away perspective view of a capacitor, in accordance with embodiments herein.

(8) FIG. **8** illustrates a cut away perspective view of a capacitor, in accordance with embodiments herein.

(9) FIG. **9** illustrates a perspective view of a capacitor, in accordance with embodiments herein.
(10) FIG. **10** illustrates a sectional view of a capacitor, in accordance with embodiments herein.
(11) FIG. **11**A illustrates a sectional view of an injection device, in accordance with embodiments herein.
(12) FIG. **11**B illustrates a sectional view of an injection device, in accordance with embodiments herein.
(13) FIG. **12** illustrates a perspective view of a capacitor assembly, in accordance with embodiments herein.
(14) FIG. **13** illustrates a perspective view of backing plate, in accordance with embodiments herein.
(15) FIG. **14** illustrates a perspective view of backing plate and electronic coupler, in accordance with embodiments herein.
(16) FIG. **15** illustrates a plan view of a backing plate and electronic coupler, in accordance with embodiments herein.
(17) FIG. **16** illustrates a plan view of a backing plate and electronic coupler, in accordance with embodiments herein.
(18) FIG. **17** illustrates a schematic diagram of an IMD in accordance with embodiments herein.
(19) FIG. **18** illustrates a schematic block diagram of an IMD in accordance with embodiments herein.

DETAILED DESCRIPTION

(20) It will be readily understood that the components of the embodiments as generally described and illustrated in the figures herein, may be arranged and designed in a wide variety of different configurations in addition to the described example embodiments. Thus, the following more detailed description of the example embodiments, as represented in the figures, is not intended to limit the scope of the embodiments, as claimed, but is merely representative of example embodiments.

(21) Reference throughout this specification to “one embodiment” or “an embodiment” (or the like) means that a particular feature, structure, or characteristic described in connection with the embodiment is included in at least one embodiment. Thus, appearances of the phrases “in one embodiment” or “in an embodiment” or the like in various places throughout this specification are not necessarily all referring to the same embodiment.

(22) Furthermore, the described features, structures, or characteristics may be combined in any suitable manner in one or more embodiments. In the following description, numerous specific details are provided to give a thorough understanding of embodiments. One skilled in the relevant art will recognize, however, that the various embodiments can be practiced without one or more of the specific details, or with other methods, components, materials, etc. In other instances, well-known structures, materials, or operations are not shown or described in detail to avoid obfuscation. The following description is intended only by way of example, and simply illustrates certain example embodiments.

(23) The methods described herein may employ structures or aspects of various embodiments (e.g., systems and/or methods) discussed herein. In various embodiments, certain operations may be omitted or added, certain operations may be combined, certain operations may be performed simultaneously, certain operations may be performed concurrently, certain operations may be split into multiple operations, certain operations may be performed in a different order, or certain operations or series of operations may be re-performed in an iterative fashion. It should be noted that, other methods may be used, in accordance with an embodiment herein. Further, wherein indicated, the methods may be fully or partially implemented by one or more processors of one or more devices or systems. While the operations of some methods may be described as performed by the processor(s) of one device, additionally, some or all of such operations may be performed by the processor(s) of another device described herein.

(24) It should be clearly understood that the various arrangements and processes broadly described and illustrated with respect to the Figures, and/or one or more individual components or elements of such arrangements and/or one or more process operations associated of such processes, can be employed independently from or together with one or more other components, elements and/or process operations described and illustrated herein. Accordingly, while various arrangements and processes are broadly contemplated, described and illustrated herein, it should be understood that they are provided merely in illustrative and non-restrictive fashion, and furthermore can be regarded as but mere examples of possible working environments in which one or more arrangements or processes may function or operate.
(25) All references, including publications, patent applications and patents, cited herein are hereby incorporated by reference to the same extent as if each reference were individually and specifically indicated to be incorporated by reference and were set forth in its entirety herein.
Terms
(26) The term “capacitor stack” refers to a group of layers placed one on top of another to provide an electrical output for a capacitor. A capacitor stack can include at least one anode layer, at least one cathode layer, and at least one electrolytic layer. Though in some embodiments plural anode layers, plural cathode layers, and plural electrolytic layers are provided. Each layer forms a portion of the thickness of the capacitor stack, where the total thickness of the capacitor stack is the combination of the thicknesses of the layers. In one example, the electric output can be an anode or a cathode, where the anode and/or cathode can be welded together and have a thickness that is less than the rest of the capacitor stack.
(27) The term “isolated” refers to two electrical components that do not pass electrical properties or characteristics to and from one another. Such isolation may be a physical isolation such that the two electrical components do not engage one another. In another example, an electrical polarity, is not passed even though engagement of the two electrical components may be presented. As an example, a capacitor stack is considered isolated from a case or cover portion when the negative electrical polarity of the anode is not passed, conducted, or the like to or from the case or covering such that the case or cover portion remains neutral.
(28) The term “ferrule” refers to a tube, such as a metal tube, that is coupled onto the end of a wire. In one example, a soft metal tube is crimped onto the end of a stranded wire to improve the connection characteristics of the wire. In addition, the tube also facilitates the passing of the wire through openings, allowing wires to be feed through the opening during manufacturing.
(29) The term “obtains” and “obtaining”, as used in connection with data, signals, information, and the like, include at least one of i) accessing memory of an external device or remote server where the data, signals, information, etc. are stored, ii) receiving the data, signals, information, etc. over a wireless communications link between the IMD and a local external device, and/or iii) receiving the data, signals, information, etc. at a remote server over a network connection. The obtaining operation, when from the perspective of an IMD, may include sensing new signals in real time, and/or accessing memory to read stored data, signals, information, etc. from memory within the IMD. The obtaining operation, when from the perspective of a local external device, includes receiving the data, signals, information, etc. at a transceiver of the local external device where the data, signals, information, etc. are transmitted from an IMD and/or a remote server. The obtaining operation may be from the perspective of a remote server, such as when receiving the data, signals, information, etc. at a network interface from a local external device and/or directly from an IMD. The remote server may also obtain the data, signals, information, etc. from local memory and/or from other memory, such as within a cloud storage environment and/or from the memory of a workstation or clinician external programmer.
(30) Embodiments may be implemented in connection with one or more implantable medical devices (IMDs). Non-limiting examples of IMDs include one or more of neurostimulator devices, implantable cardiac monitoring and/or therapy devices. For example, the IMD may represent a

cardiac monitoring device, pacemaker, cardioverter, cardiac rhythm management device, implantable cardioverter defibrillator (ICD), neurostimulator, leadless monitoring device, leadless pacemaker, an external shocking device (e.g., an external wearable defibrillator), and the like. For example, the IMD may be a subcutaneous IMD that includes one or more structural and/or functional aspects of the device(s) described in U.S. application Ser. No. 15/973,195, titled "Subcutaneous Implantation Medical Device With Multiple Parasternal-Anterior Electrodes" and filed May 7, 2018; U.S. application Ser. No. 15/973,219, titled "Implantable Medical Systems And Methods Including Pulse Generators And Leads" filed May 7, 2018; U.S. application Ser. No. 15/973,249, titled "Single Site Implantation Methods For Medical Devices Having Multiple Leads", filed May 7, 2018, which are hereby incorporated by reference in their entireties. Additionally or alternatively, the IMD may include one or more structural and/or functional aspects of the device(s) described in U.S. Pat. No. 9,333,351 "Neurostimulation Method and System to Treat Apnea" and U.S. Pat. No. 9,044,710 "System and Methods for Providing A Distributed Virtual Stimulation Cathode for Use with an Implantable Neurostimulation System", which are hereby incorporated by reference. Further, one or more combinations of IMDs may be utilized from the above incorporated patents and applications in accordance with embodiments herein.

(31) Additionally or alternatively, the IMD may include one or more structural and/or functional aspects of the device(s) described in U.S. Pat. No. 9,216,285 "Leadless Implantable Medical Device Having Removable and Fixed Components" and U.S. Pat. No. 8,831,747 "Leadless Neurostimulation Device and Method Including the Same", which are hereby incorporated by reference. Additionally or alternatively, the IMD may include one or more structural and/or functional aspects of the device(s) described in U.S. Pat. No. 8,391,980 "Method and System for Identifying a Potential Lead Failure in an Implantable Medical Device", U.S. Pat. No. 9,232,485 "System and Method for Selectively Communicating with an Implantable Medical Device", EP Application No. 0070404 "Defibrillator" and, U.S. Pat. No. 5,334,045 "Universal Cable Connector for Temporarily Connecting Implantable Leads and Implantable Medical Devices with a Non-Implantable System Analyzer", U.S. patent application Ser. No. 15/973,126, titled "Method And System For Second Pass Confirmation Of Detected Cardiac Arrhythmic Patterns"; U.S. patent application Ser. No. 15/973,351, Titled "Method And System To Detect R-Waves In Cardiac Arrhythmic Patterns"; U.S. patent application Ser. No. 15/973,307, titled "Method And System To Detect Post Ventricular Contractions In Cardiac Arrhythmic Patterns"; and U.S. patent application Ser. No. 16/399,813, titled "Method And System To Detect Noise In Cardiac Arrhythmic Patterns" which are hereby incorporated by reference.

(32) Additionally or alternatively, the IMD may be a leadless cardiac monitor (ICM) that includes one or more structural and/or functional aspects of the device(s) described in U.S. patent application Ser. No. 15/084,373, filed Mar. 29, 2016, entitled, "Method and System to Discriminate Rhythm Patterns in Cardiac Activity"; U.S. patent application Ser. No. 15/973,126, titled "Method And System For Second Pass Confirmation Of Detected Cardiac Arrhythmic Patterns"; U.S. patent application Ser. No. 15/973,351, titled "Method And System To Detect R-Waves In Cardiac Arrhythmic Patterns"; U.S. patent application Ser. No. 15/973,307, titled "Method And System To Detect Post Ventricular Contractions In Cardiac Arrhythmic Patterns"; and U.S. patent application Ser. No. 16/399,813, titled "Method And System To Detect Noise In Cardiac Arrhythmic Patterns", which are expressly incorporated herein by reference.

(33) Provided is an electrolytic capacitor having an anode that has a surface area of 30-40 million tunnels/cm{circumflex over ( )}2 after an etching manufacturing technique as a result of utilizing molybdic acid to provide galvanic aluminum dissociation in a low pH etch solution before the electrochemical process is implemented to increase initiation sites before etching. After etching, an electrochemical widening step is used to increase the tunnel diameter to ensure the formation oxide will not close off the tunnels. As a result, the energy density of the anode is increased by as much as 10%, allowing a smaller, less voluminous anode, and consequently capacitor. Still, in

applications such as IMDs, while decreasing the overall size can be beneficial, in addition, by keeping the same size of IMD, benefits can also be realized. In particular, IMDs are sized to be acceptable for a patient using the IMD, so by decreasing the size of the anode and thus capacitor internally within the IMD without decreasing the overall size of the IMD, manufacturing and packaging improvements are provided to reduce BOM costs, reduce manufacturing complexity, and provide additional protections not realized without the molybdic acid manufacturing technique.
(34) FIG. **1** illustrates a method **100** for manufacturing a capacitor. In one example, the capacitor is a high voltage capacitor that can have an operating voltage of between 350-475 Volts and specifically between 400-465 Volts. In one example, the capacitor is utilized in an IMD, including in an implantable cardioverter defibrillator (ICD).
(35) At **102**, a capacitor stack is formed that includes at least one anode layer, at least one cathode layer, and at least one electrolytic layer that is disposed between an anode layer and a cathode layer. The anode layer has a surface area of at least 40 million tunnels/cm2. In one example, in order to achieve this surface area, the anode is formed utilizing molybdic acid that allows for galvanic aluminum dissociation in a low pH etch solution before etching occurs. As a result, initiation sites are increased resulting in a capacitance increase compared to other etching techniques.
(36) Because of the increase in energy density of the anode resulting from the increased surface area achieved using the molybdic acid, the anode layer, cathode layer, and electrolytic layer are each sized and shaped to facilitate manufacturing. In particular, when the capacitor is utilized in an IMD, strict spatial requirements are presented. Because of the spatial requirements, when using other etching techniques that do not achieve the surface area presented by use of the molybdic acid, the anode layer must be utilized completely for surface area and functional purposes. With the increase in surface area realized by utilizing the molybdic acid etching technique, the reduced size of the anode layer, and consequently, the cathode layer and electrolytic layer may be utilized to enhance manufacturing capabilities.
(37) In one example, the anode layer, cathode layer, and electrolytic layer can be designed to have peripheries with straight and angled edges, along with increased radii at transitions between the edges. By having a capacitor stack periphery with simple geometries, manufacturing of the capacitor stack is simplified, leading to automation, while decreasing cracking in individual layers as a result to inconsistent geometries. In one example, manual taping of the capacitor stack is not required, and the process of forming the capacitor stack is completely automated. To this end, while adhesive tape may be utilized to bundle the capacitor stack, or to cover seams between layers, because of the simplified, repeatable geometry of the capacitor stack periphery, such adhesive tape may be automatically applied. Alternatively, the amount of time for manual placement of the adhesive tape is reduced.
(38) At **104**, a first cover portion is formed. In one example, the first cover portion is formed through an injection molding process, and specifically in one embodiment a plastic injection molding process. As such, the first cover portion comprises an injection molded plastic. In this manner, the first cover portion functions as a plastic boot that encases a portion of the capacitor stack. As used herein, the term boot refers to a covering, that has an open end for receiving a capacitor stack. The covering can be plastic, metal, ceramic, etc., although the covering typically is a plastic injection molded cover portion.
(39) In one example, ferrules that are to be coupled to an anode and cathode of the capacitor stack can be positioned during the injection molding process to ensure an appropriate mechanical and electrical coupling to the anode and cathode. By using a manufacturing process such as injection molding, the formation of the first cover portion can be automated, and repeatable such that the exact same first cover portion can be formed from the same mold. This also allows for replacement of such a first cover portion as needed, and increases the speed of manufacturing time.
(40) At **106**, a second cover portion is formed. In one example, the second cover portion is made from a progressive die manufacturing method to form a metal case. The progressive die

manufacturing process can include continuously feeding metallic material into a device for stamping, punching, coining, bending, or the like into the geometry and shape presented by the die. After formation, the second cover portion (e.g. metal case) is then ejected for coupling with the first cover portion (e.g. plastic boot). Consequently, as a result of the simplified geometry of the capacitor stack, a matching first cover portion and second cover portion, each with a simplified geometry can be formed using an automated process such an injection molding, progressive die manufacturing, or the like. Therefore, manufacturing is simplified, and more capacitors may be manufactured in a determined period of time than compared to current manufacturing processes.

(41) At **108**, an anode and cathode are formed. In one example, the anode is formed by welding the anode layers together at an anode periphery of the anode layers. Similarly, in one example, the cathode if formed by welding cathode layers together at the cathode periphery of cathode layers adjacent the anode. In one example, the cathode includes a titanium cathode flat that is welded to an aluminum wire assembly. A ferrule of the aluminum wire assembly, and a ferrule coupled to the anode can then be feed through a sealing element that guides each ferrule through openings within the first cover portion and/or second cover portion. The sealing elements function to prevent the ferrules from engaging the first cover portion and/or second cover portion and sealing the capacitor stack from the exterior environment. In this manner, the anode is isolated from the second cover portion (e.g. metal case) to provide a neutral output. An anode and cathode wire seal may be provided that does not have a parting line in the sealing surface, resulting in higher reliability of the sealing surface to decrease electrolyte leaks during manufacturing and use.

(42) At **110**, an adhesive tape is adhered around the capacitor stack periphery for coupling with the first cover portion and/or the second cover portion. In one example, the tape includes a stainless steel backing band with adhesive that couples to either the first cover portion, and/or the second cover portion. The adhesive tape functions to seal the capacitor stack, and prevent leakage from the electrolytic layers. Additionally, because of the simple geometries of the capacitor stack periphery, the adhesive tape can be automatically applied about the capacitor stack.

(43) At **112**, optionally, an opening that is disposed through the first cover portion, and/or second cover portion, and utilized for welding can be sealed. In particular, an opening may be formed in either the first cover portion or second cover portion to access the anode, cathode, capacitor stack, etc. for the purposes of welding therein. In one example, a ball seal is provided within an insert in order to seal the cavity formed by the coupling of the first cover portion and the second cover portion. As such, a sealed cavity is presented.

(44) As provided, because of the decrease in size of the anode, due to the increase in surface area of the anode from using the molybdic acid etching technique, the capacitor stack periphery may be formed with simple geometries and then disposed with a shell body formed from a first cover portion and second cover portion. Such simple geometries permit the first cover portion and second cover portion to be formed using automated, repeatable manufacturing processes, improves protections, and reduces overall cost of the capacitor. To this end, the capacitor can also be reduced in size depending on the voltage requirements of the capacitor.

(45) FIGS. **2-7** illustrate views of a capacitor **200**. In one example, the capacitor **200** is formed utilizing the method of FIG. **1**. In particular, the capacitor is a high voltage capacitor that can have an operating voltage of between 350-475 Volts and specifically between 400-465 Volts. In one example, the capacitor **200** is utilized in an IMD, including in an implantable cardioverter defibrillator (ICD).

(46) The capacitor **200** includes a capacitor stack **202** that is protected, and covered by a shell body **204** (FIG. **4**) that includes a first cover portion **206** and a second cover portion **208** that mechanically couple to one another and define a cavity **210** that receives a capacitor stack **202**. In one example, the first cover portion **206** may be made of a plastic material, and represent a plastic boot, while the second cover portion **208** is made of a stainless steel material that functions to protect the capacitor stack **202**. While in one example the first cover portion **206** and second cover

portion **208** can be of similar size such as when forming the shell body **204**, in other example embodiments, the second cover portion **208** may be slightly larger than the first cover portion **206** such that the first cover portion **206** can be received by the second cover portion **208**

(47) The capacitor stack **202** includes plural anode layers **212** and cathode layers **214** stacked one on top of another with an electrolytic layer **216** disposed between each anode layer **212** and cathode layer **214**. The anode layer **212** is formed utilizing an etching manufacturing technique utilizing molybdic acid to provide galvanic aluminum dissociation in a low pH etch solution. Consequently, the anode has a surface area of 30-40 million tunnels/cm{circumflex over ( )}2 including an increase in tunnel diameter to ensure the formation oxide does not close the tunnels. As a result, the energy density of the anode is increased. The electrolytic layer **216**, or paper, include electrolytes allowing the capacitor to hold a charge therein.

(48) Plural sections of adhesive tape **217** hold the multi-layers of the capacitor stack **202** together. In one example, the adhesive tape **217** is a metal tape such as stainless steel. In another example, the tape can be a PEEK tape, or include a layer of PEEK tape. In particular, PEEK tape does not break down under increased temperatures, resulting in increased life of the capacitor. In other examples, another corrosive resistant material can be utilized.

(49) The capacitor stack **202** also includes first and second alignment slots **218**, **220** provide an opening for a fastener to secure the first cover portion **206** and second cover portion **208**, and also aligns the anode layers **212**, cathode layers **214**, with the electrolytic layers **216**. In one example, the first and second alignment slots **218** and **220** are generally arcuate in shape. In particular, the first alignment slots align the cathode layers **214** and electrolytic layers **216**, while the second alignment slots align the anode layers **212** and electrolytic layers **216**. Because of etching manufacturing technique utilizing molybdic acid, the first and second alignment slots **218**, **220** may be made for alignment and fastening functionality, while the capacitor stack still functions as a high voltage capacitor as a result of the increased energy density of the anode. Similarly, the capacitor stack periphery **221** may have a more pronounced radii or curvature, allowing the shell body **204** to have a simple design. To this end, the capacitor stack **202** has a capacitor stack periphery **221** that includes simple geometries such as straight edges, angled straight edges, arcuate transitions with pronounced radii or curvature, etc. Specifically, in one embodiment, the periphery of the anode layer(s), the periphery of the cathode layer(s), and the periphery of the electrolytic layer(s) all align to form the capacitor stack periphery with the simplified geometries.

(50) The capacitor stack **202** also has a compressed anode portion **222** and compressed cathode portion **224** that present the input and output of the capacitor. The compressed anode portion **222** and compressed cathode portion **224** in one example are each welded together at an end of the capacitor stack **202** such that neither the compressed anode portion **222**, nor the compressed cathode portion **224** engage the shell body **204**. In particular, when described as compressed, does not indicate that an individual anode layer or cathode layer are compressed, instead, the term compressed is indicating the width of the compressed anode portion **222** and compressed cathode portion **224** is less than the width of the rest of the combined anode layers **212** and combined cathode layers **214**. Specifically, by having the compressed anode portion **222** and compressed cathode portion **224** be a smaller width, and not engaging either the first cover portion **206** or second cover portion **208** of the shell body **204**, the capacitor remains neutral, instead of having a negative charge. Consequently, additional electronic components are not needed to covert a negatively charged output to a neutral output. Instead by effectively utilizing the spatial arrangement of the capacitor stack **202**, such a neutral output is accomplished.

(51) As best illustrated in FIG. **2**, the capacitor stack **202** additionally includes a first ferrule support structure **226**, and second ferrule support structure **228**. The first ferrule support structure **226** supports a first ferrule **230** that couples to the compressed anode portion **222**, while the second ferrule support structure **228** supports a second ferrule **232** that couples to the compressed cathode portion **224**. In one example, the first and second ferrules **230**, **232** each include an insulated

material such as rubber to frictionally engage each ferrule **230**, **232**. The first and second ferrule support structures **226**, **228** prevent the first and second ferrules **230**, **232** from engaging the first cover portion **206** or second cover portion **208** of the shell body **204**, again allowing for a neutral output from the capacitor **200**. In addition, the first ferrule support structure **226** and second ferrule support structure **228** have simple geometries, making reproduction of each facilitated. In addition, because the first cover portion **206** can be injection molded as a boot, the ferrules **230**, **232** are positioned for feed through from openings **233** (FIG. **3**) in the clam shell body **204**. In addition, edge taping is eliminated, again eliminating manual labor, decreasing costs, and increasing automation ability. As an additional advantage, the capacitor stack **202** is isolated from the second cover portion **208** to provide a neutrally charged second cover portion **208**. As a result, when the capacitor **200** is within an implanted medical device, the second cover portion **208** is neutrally charged, requiring no additional circuitry to vary a negative output, eliminating electronic components of the capacitor **200**.

(52) The first cover portion **206** includes plural recesses **234** that align with the adhesive tape **217** that holds the multi-layers of the capacitor stack **202** together. In one example, the first cover portion **206** is considered an exoskeleton of the capacitor. The first cover portion **206** has a first cover portion periphery **236** that includes a front **238** that arcuately transitions to an input side **240** that includes a first portion **242** and a second portion **244** angled from the first portion **242**, and having an opening therein configured to receive ferrules of the capacitor stack. The input side **240** only has the simple geometry of the first portion **242** angled to the second portion **244** with no complex geometries. To this end, the input side **240** also arcuately transitions to a back **246** of the first cover portion periphery **236**. The arcuate transition between the front **238** and input side **240**, along with the arcuate transition between the input side **240** and back **246** have radii that again provide simple geometries. The back **246** extends to another arcuate transition to an arcuate side **248**. The arcuate side **248** is generally arcuate, curving to another arcuate transition with the front **238**. The first cover portion **206** along the front **238**, back **246**, input side **240**, or arcuate side **248** may include fastener bodies **250** that are of size and shape to accommodate the capacitor stack, and receive fasteners to couple to the second cover portion **208**, and secure the first cover portion **206** to the second cover portion **208** with the capacitor stack **202** disposed therein. The fastener bodies **250** may include cavities, indentations, openings, or the like to accommodate the coupling of the first cover portion **206** and second cover portion **208**.

(53) As also illustrated in FIG. **5**, an auxiliary tape **251** can be placed around the capacitor stack **202** to simplify the design of the case. In one example, the auxiliary tape **251** includes a stainless steel backing band with an adhesive connection to the second cover portion **208**. In this manner, tolerance issues can be addressed with the auxiliary tape **251**. As a result, a lower cost for the second cover portion **208** is provided. In addition, because of the simple geometries, and auxiliary tape **251**, progressive dies can be utilized for forming the second cover portion **206**, providing ease of manufacturing. The auxiliary tape **251** also provides a back up band to prevent laser heat during a welding manufacturing process from engaging and/or damaging the second cover portion **206**.

(54) With reference back to FIG. **2**, the second cover portion **208**, similar to the first cover portion **206**, includes a plural recesses **252** that align with the adhesive tape **217** that bundles the capacitor stack **202**. In one example, the second cover portion **208** is considered an exoskeleton of the capacitor. The second cover portion **208** has a second cover portion periphery **254** that similar to the first cover portion **206** that includes a front **256** that arcuately transitions to an input side **258** that includes a first portion **260** and a second portion **262** angled from the first portion **260**, and having an opening **264** (FIG. **3**) therein configured to receive ferrules of the capacitor stack **202**. The input side **258** only has the simple geometry of the first portion **260** angled to the second portion **262** with no complex geometries. To this end, the input side **258** also arcuately transitions to a back **268** of the second cover portion periphery **254**. The arcuate transition between the front **256** and input side **258**, along with the arcuate transition between the input side **258** and back **268**

have radii that again provide simple geometries. The back **268** extends to another arcuate transition to an arcuate side **270**. The arcuate side **270** is generally arcuate, curving to another arcuate transition with the front **256**. The second cover portion **208** along the front **256**, back **268**, input side **258**, or arcuate side may include fastener bodies **246** that are of size and shape to accommodate the capacitor stack, and receive fasteners to couple to the second cover portion, and secure the first cover portion **206** to the second cover portion **208** with the capacitor stack disposed therein. The fastener bodies **272** may include cavities, indentations, openings, or the like to accommodate the coupling of the first cover portion **206** and second cover portion **208**. Specifically, the first cover portion periphery **236** and the second cover portion periphery **254** align with the capacitor stack periphery **221** such that the first cover portion **206** and second cover portion **208** form a shell body **204** for encasing the capacitor stack **202** therein.
(55) The second cover portion **208** in one example is a stainless steel case. The shape, tolerances, and geometry of the second cover portion **208** allows for a progressive die for case creation, improving the manufacturing process. Specifically, the higher tolerances allow for lower cost case design, as simpler geometries are achieved. The simple geometries also promote automation, and facilitate welding processes. As a result, the ease of manufacturing is enhanced, vastly improving over current manufacturing methodologies.
(56) The first cover portion **206**, and second cover portion **208** are of similar size and shape such that the first cover portion **206** matingly receives the second cover portion **208** to form the shell body **204** that protects the capacitor stack **202**. In one example, the shell body **204** is a clam shell body (FIG. **3**). In addition, because of the simple geometries the first cover portion **206** be manufactured using an injection molding process as an injection molded boot. This injection molded boot can then be received by the second cover portion **208** that can be a stainless steel casing. In this manner, compared to previous manufacturing techniques, the injection molding process is easy to replicate, no customization is required, and the number of shell bodies that can be manufactured per hour is greatly increased. As a result, a better, less expensive manufacturing process is provided. Specifically, with the anode taking up lest spatial requirements, the geometries of the first cover portion **206** and second cover portion **208** can be simplified, resulting in an improved manufacturing process.
(57) For example, the simplification of the anode layers **212**, cathode layers **214**, and electrolytic layer **216** improves the quality of the capacitor stack **202**. As illustrated in FIG. **5**, increases radii for corners or transitions of the capacitor stack **202** allows for alignment of each layer **212**, **214**, **216** of the capacitor stack **202**. Specifically, the outside edge, or periphery, of each layer **212**, **214**, **216** align to form the capacitor stack **221**, eliminating the need for cathode tabs that have to bend for proper alignment. Such elimination of the cathode tabs lends to automation of the stacking process, thus improving manufacturing of the capacitor stack **202**. The increased radii for transitions of the periphery of the anode layers **212**, cathode layers **214**, and electrolytic layer **216** also results in decreased cracking of each layer, including decreased anode cracking that can lead to lower yield. Consequently, yield is increased, and the life of the capacitor increased because of the simplified spatial design.
(58) In addition, utilizing a first cover portion **206** that can be an injection molded boot cover around the capacitor stack **202** compared to the use of PEEK thin pockets presents numerous advantages. For example, the thicker boot cover allows for higher voltage withstand compared to a PEEK pocket. In addition, the thicker plastic material of such a boot allows for injection molding, presenting a more cost effective, simpler manufacturing process. In addition, the thick material also prevents electrical shorts, resulting in a more reliable capacitor. In addition, the amount of edge taping that is typically performed in a manual labor step is decreased, again, making for a faster and more time effective manufacturing process. In addition, such manufacturing is conducive to automation, again improving upon the manufacturing process.
(59) FIG. **8** illustrates an alternative embodiment of a capacitor **800**. In one example, the capacitor

800 of FIG. **8** is the capacitor of FIGS. **2-7**. In particular, the capacitor is a high voltage capacitor can have an operating voltage of between 350-475 Volts and specifically between 400-465 Volts. In one example, the capacitor **800** is utilized in an IMD, including in an implantable cardioverter defibrillator (ICD).

(60) The capacitor **800** includes a capacitor stack **802** as described in relation to FIGS. **2-7**. The capacitor stack **802** includes a compressed anode portion **822** and compressed cathode portion **824** that present the input and output of the capacitor. The compressed anode portion **822** and compressed cathode portion **824** in one example are each welded together at an end of the capacitor stack **802** such that neither the compressed anode portion **822**, nor the compressed cathode portion **824** engage a shell body (not shown).

(61) In this embodiment, the compressed cathode portion **824** is resistance welded into a single stack, layer, or flat **825**. In one example, the compressed cathode portion **824** is a titanium material. The compressed cathode portion **824** is coupled to a ferrule **828** via a wire assembly **829** to provide for a negative connection disposed outside of the shell body. In one example, the wire assembly **829** includes low resistance aluminum wire material to reduce internal resistance within the capacitor **800**. The wire assembly **829** can include a flat wire adapter **831** coupled to a wire coil **833**, or round wire. In one example, the flat wire adapter **831** is comprised of a titanium material, while the wire coil **833** comprises the aluminum material to provide the electrical coupling.

(62) FIGS. **9-10** illustrate views of a capacitor **900**, that in one example is the capacitor of FIGS. **2-7**. In one example, the capacitor **900** is a high voltage capacitor can have an operating voltage of between 350-475 Volts and specifically between 400-465 Volts. In one example, the capacitor **900** is utilized in an IMD, including in an implantable cardioverter defibrillator (ICD).

(63) The capacitor **900** includes a capacitor stack (not shown) that is protected, and covered by a shell body **904** that includes a first cover portion **906** and a second cover portion **908** that mechanically couple to one another and define a cavity that receives a capacitor stack. In one example, the first cover portion **906** may be made of a plastic material, and represent a plastic boot, while the second cover portion **908** is made of a stainless steel material that is considered a stainless steel case that functions to protect the capacitor stack **902**.

(64) Disposed within the first cover portion **906** and second cover portion **908** is a seal plug assembly **911** that include a plug **913**. The plug in one example is press fit into the first cover portion **906** and/or second cover portion **908** during a welding process. In this manner, the shell **904** is sealed to contaminants after formation.

(65) FIG. **10** illustrates one example of how the seal plug assembly **911** may be sealed. As illustrated, a first opening **915** is provided in the first cover portion **906**, and a second opening **917** is provided in the second cover portion **908** that is encased by the first cover portion **906**. In one example, the first cover portion **906** is made of a stainless steel material, while the second cover portion **908** is made of a plastic material.

(66) A first insert **919** is disposed through the first opening **915**, second opening **917**, and within a capacitor stack **902**. In one example, the first insert **919** is a stainless steel welded insert. In addition, a second insert **921** is disposed through the first opening **915** and second **917** adjacent the first insert **919**, and having a third opening **923** disposed therethrough. In one example, the second insert **921** is press in molded and trimmed, and made of a plastic material. Disposed within the third opening **923** is a ball element **925**, that in one example is a stainless steel seal ball. The ball element **925** seals the third opening **923** such that the first insert **919**, second insert **921**, and ball element seal the interior of the shell from contaminants. The ball element **925** functions as a low cost seal that avoids the need for a more expensive and complex laser welding operation, reducing manufacturing cost and time.

(67) FIGS. **11**A and **11**B illustrate an injection molding devices **1100**A, **1100**B utilized to feed through the shell body and provide an anode and cathode wire seal without a parting line in the sealing surfaces. The injection molding devices **1100**A, **1100**B include a molding body **1102**A,

1102B that in one example is made of a rubber material and feed through an insert. To this end, the molding body **1102**A, **1102**B includes an outer sealing surface **1104**A, **1104**B and an inner sealing surface **1106**A, **1106**B where the inner sealing surface defines an injection conduit **1108**A, **1108**B. In one example, as illustrated in FIG. **11**A, the injection conduit **1108**A has a constant diameter, whereas as illustrated in FIG. **11**B, the injection conduit **1108**B includes numerous sections **1110**B, **1112**B, **1114**B that taper. In each instance, the wire seal is provided without a parting line, improving the performance of the capacitor by eliminating internal resistances that can cause inefficiencies, and excess heat that can also damage the capacitor. In addition, enhanced reliability of the sealing surface decreases electrolyte leaks during manufacturing and use.

(68) FIG. **12** illustrates a capacitor assembly **1200** formed from first capacitor **1202**, and a second capacitor **1204** stacked on one another to form a signal capacitor. The first capacitor **1202**, and second capacitor **1204** may each be any of the capacitors presented in FIGS. **2-7**. In particular, because each capacitor **1202**, **1204** is formed utilizing an etching technique utilizing molybdic acid, a first cover portion **1206** that can be a boot, and a second cover portion **1208** that can be a case, can be reproduced to be the identical size and stackable on top of one another. When stacked on top of one another, ferrules **1207** of the first capacitor **1202**, and ferrules **1207**, **1209** of the second capacitor **1204** are coupled via a backing plate **1210** to an electronic coupler **1212**. The capacitor assembly **1200** in one example operates in range between 700 Volts and 950 Volts, and more specifically between 800 Volts and 925 Volts.

(69) The backing plate **1210** in one example is made from a plastic material. The backing plate **1210** is also configured to engage ferrule support structures **1213**, **1215** of the first capacitor **1202** and second capacitor **1204** respectfully. In one example, each ferrule support structure **1213**, **1215** is comprised of rubber material, and function as rubber stops of each capacitor **1202**, **1204** that engage the backing plate **1210**.

(70) Regarding the coupling of the ferrules **1207**, **1209** to the backing plate **1210**, one ferrule **1207** of the first capacitor **1202** is coupled to a first anode, and one ferrule **1209** of the second capacitor **1204** is coupled to a second anode. Similarly, one ferrule **1207** of the first capacitor is coupled to a first cathode, and one ferrule **1209** of the second capacitor **1204** is coupled to a second cathode. Each ferrule **1207**, **1209** of each capacitor **1202**, **1204** couples to the backing plate **1210** to provide a combined anode ferrule **1214** and a combined cathode ferrule **1216**. The combined anode ferrule **1214** and combined cathode ferrule **1216** electrically couple into the electronic coupler **1212** along with a high voltage add-on wire **1226**. The electronic coupler **1212** includes plural pin elements **1218** that mechanically couple the electronic coupler **1212** to a substrate such as a circuit board, printed circuit board, or the like that electrically couples electronic components.

(71) FIG. **13** illustrates a cutaway perspective view of the backing plate **1210** to show how the individual ferrules **1207**A, **1207**B, **1209**A, **1209**B of each capacitor **1202**, **1204** are received and coupled to the electronic coupler **1212**. As illustrated, the backing plate **1210** includes indentations or grooves **1220** for receiving each ferrule **1207**A, **1207**B, **1209**A, **1209**B of the first capacitor **1202** and second capacitor **1204**. As illustrated, the positive ferrule **1207**A of the first capacitor **1202** is coupled to the cathode of the capacitor stack of the first capacitor **1202** and is coupled on a first side **1222** of the backing plate **1210**, while the negative ferrule **1207**B of the first capacitor **1202** is coupled to the anode of the capacitor stack of the first capacitor **1202** and is coupled on a second side **1224** of the backing plate **1210**. In particular, the positive ferrule **1207**A of the first capacitor **1202** in one example is welded to the backing plate **1210**.

(72) Meanwhile, the positive ferrule **1209**A of the second capacitor **1204** is coupled to the cathode of the capacitor stack of the second capacitor **1204** and is coupled on the first side **1222** of the backing plate **1210**, wherein the negative ferrule **1209**B of the second capacitor **1204** is coupled to the anode of the capacitor stack of the second capacitor **1204**, and is coupled on the second side **1224** of the backing plate **1210**. In particular, in one example, the negative ferrule **1209**B of the second capacitor **1204** is welded to the backing plate **1210**.

(73) In addition, a high voltage add-on wire **1226** is also welded to the backing plate **1210**. In this manner, the backing plate **1210** allows for the positive, negative, and high voltage wire to be welded at the same manufacturing step. As a result, ease of manufacturing is realized for the welding operation.
(74) FIGS. **14-16** illustrate views of the backing plate **1210** and electronic coupler **1212** to illustrate how the backing plate **1210** and electronic coupler **1212** attach to one another. Specifically, the backing plate **1210** in one example includes post elements **1228** that align with openings within the electronic coupler **1212**, while the electronic coupler **1212**, includes a post element **1230** that aligns with and is received in an opening within the backing plate **1210**. In one example, the post elements **1228** of the backing plate **1210**, and post element **1230** of the electronic coupler **1212** are each made of a plastic material. Each of the posts **1228**, **1230** ensure the backing plate **1210** and electronic coupler **1212** are aligned. By ensuring the alignment, a mechanical coupling of the backing plate **1210** and electronic coupler **1212** is provided such that electrical coupling between the first capacitor and second capacitor to the pin elements **1218** of the electronic coupler **1212** is also presented. In particular, the electronic coupler **1212** includes a housing **1232** that defines a first cavity **1234** for receiving a positive input, a second cavity **1236** for receiving a high voltage input, and a third cavity **1238** for receiving a negative input from the backing plate **1210**. Each cavity may include additional structure, including nut elements, arcuate walls, or the like that direct the positive input, high voltage input, and negative input to mechanically and electrically couple to the pin elements **1218**.
(75) FIG. **17** illustrates an IMD **1700** that in one example is a dual-chamber stimulation device capable of treating both fast and slow arrhythmias with stimulation therapy, including cardioversion, defibrillation, anti-tachycardia pacing and pacing stimulation, as well as capable of detecting heart failure, evaluating its severity, tracking the progression thereof, and controlling the delivery of therapy and warnings in response thereto. The IMD **1700** may be controlled to sense atrial and ventricular waveforms of interest, discriminate between two or more ventricular waveforms of interest, deliver stimulus pulses or shocks, and inhibit application of a stimulation pulse to a heart based on the discrimination between the waveforms of interest and the like. Exemplary structures for the IMD **1700** are discussed and illustrated in the drawings herewith.
(76) The IMD **1700** includes a housing **1702** that is joined to a header assembly **1709** that holds receptacle connectors connected to a right ventricular lead **1710**, a right atrial lead **1712**, and a coronary sinus lead **1714**, respectively. The leads **1712**, **1714** and **1710** measure cardiac signals of the heart. The right atrial lead **1712** includes an atrial tip electrode **1718** and an atrial ring electrode **1720**. The coronary sinus lead **1714** includes a left atrial ring electrode **1728**, a left atrial coil electrode **1730** and one or more left ventricular electrodes **1732-1738** (e.g., also referred to as P**1**, M**1**, M**2** and D**1**) to form a multi-pole LV electrode combination. The right ventricular lead **1710** includes an RV tip electrode **1726**, an RV ring electrode **1724**, an RV coil electrode **1722**, and an SVC coil electrode **1716**. The leads **1712**, **1714** and **1710** detect IEGM signals that are processed and analyzed as described herein. The leads **1712**, **1714** and **1710** also delivery therapies as described herein.
(77) During implantation, an external device **1704** is connected to one or more of the leads **1712**, **1714** and **1710** through temporary inputs **1703**. The inputs **1703** of the external device **1704** receive IEGM signals from the leads **1712**, **1714** and **1710** during implantation and display the IEGM signals to the physician on a display. Hence, the external device **1704** receives the IEGM cardiac signals through telemetry circuit inputs. The physician or another user controls operation of the external device **1704** through a user interface. While the example embodiment of FIG. **17** illustrates an IMD **1700** that includes leads, such embodiment is for exemplary purposes only, in other example embodiments, the IMD may be a leadless IMD.
(78) FIG. **18** illustrates an example block diagram of a IMD **1800** that is implanted into the patient as part of the implantable cardiac system. The IMD **1800** may be implemented as a full-function

biventricular pacemaker, equipped with both atrial and ventricular sensing and pacing circuitry for four chamber sensing and stimulation therapy (including both pacing and shock treatment). Optionally, the IMD **1800** may provide full-function cardiac resynchronization therapy. Alternatively, the IMD **1800** may be implemented with a reduced set of functions and components. For instance, the monitoring device may be implemented without ventricular sensing and pacing.

(79) The IMD **1800** has a housing **1801** to hold the electronic/computing components. The housing **1801** (which is often referred to as the "can", "case", "encasing", or "case electrode") may be programmably selected to act as the return electrode for certain stimulus modes. Housing **1801** further includes a connector (not shown) with a plurality of terminals **1802**, **1805**, **1806**, **1808**, and **1811**. The type and location of each electrode may vary. For example, the electrodes may include various combinations of ring, tip, coil and shocking electrodes and the like.

(80) The IMD **1800** also includes a telemetry circuit **1834** that as a primary function allows intracardiac electrograms and status information relating to the operation of the IMD **1800** (as contained in the microcontroller **1864** or memory **1852**) to be sent to the external device **1804** through the established communication link **1850**.

(81) The programmable microcontroller **1864** controls various operations of the IMD **1800**. Microcontroller **1864** includes a microprocessor (or equivalent control circuitry), RAM and/or ROM memory, logic and timing circuitry, state machine circuitry, and I/O circuitry. The IMD **1800** further includes a first chamber pulse generator **1874** that generates stimulation pulses for delivery by one or more electrodes coupled thereto. The pulse generator **1874** is controlled by the microcontroller **1864** via control signal **1876**. The pulse generator **1874** is coupled to the select electrode(s) via an electrode configuration switch **1892**, which includes multiple switches for connecting the desired electrodes to the appropriate I/O circuits, thereby facilitating electrode programmability. The switch **1892** is controlled by a control signal from the microcontroller **1864**.

(82) Microcontroller **1864** is illustrated to include timing control circuitry **1866** to control the timing of the stimulation pulses (e.g., pacing rate, atrio-ventricular (AV) delay, atrial interconduction (A-A) delay, or ventricular interconduction (V-V) delay, etc.). Microcontroller **1864** also has an arrhythmia detector **1868** for detecting arrhythmia conditions. Although not shown, the microcontroller **1864** may further include other dedicated circuitry and/or firmware/software components that assist in monitoring various conditions of the patient's heart and managing pacing therapies.

(83) The IMD **1800** also includes one or more sensors **1870**. The one or more sensors **1870** can include physiological sensors that detect characteristics associated with the heart of the patient. Alternatively, the one or more sensors **1870** can be environmental sensors that detect characteristics associated with the environment of the patient.

(84) The IMD **1800** is further equipped with a communication modem (modulator/demodulator) to enable wireless communication with other devices, implanted devices, and/or external devices. The IMD **1800** includes sensing circuitry **1880** selectively coupled to one or more electrodes that perform sensing operations, through the switch **1892**, to detect the presence of cardiac activity.

(85) The output of the sensing circuitry **1880** is connected to the microcontroller **1864** which, in turn, triggers or inhibits the pulse generator **1874** in response to the absence or presence of cardiac activity. The sensing circuitry **1880** receives a control signal **1878** from the microcontroller **1864** for purposes of controlling the gain, threshold, polarization charge removal circuitry (not shown), and the timing of any blocking circuitry (not shown) coupled to the inputs of the sensing circuitry.

(86) In the example of FIG. **18**, a single sensing circuit **1880** is illustrated. Optionally, the IMD **1800** may include multiple sensing circuit, similar to sensing circuitry **1880**, where each sensing circuit is coupled to one or more electrodes and controlled by the microcontroller **1864** to sense electrical activity detected at the corresponding one or more electrodes. The sensing circuitry **1880** may operate in a unipolar sensing configuration or in a bipolar sensing configuration. The IMD **1800** further includes an analog-to-digital (ND) data acquisition system (DAS) **1890** coupled to one

or more electrodes via the switch **1892** to sample cardiac signals across any pair of desired electrodes.
(87) The microcontroller **1864** is also coupled to a memory **1852** by a suitable data/address bus **1862**. The programmable operating parameters used by the microcontroller **1864** are stored in memory **1852** and used to customize the operation of the IMD **1800** to suit the needs of a particular patient. Such operating parameters define, for example, pacing pulse amplitude, pulse duration, electrode polarity, rate, sensitivity, automatic features, arrhythmia detection criteria, and the amplitude, waveshape and vector of each shocking pulse to be delivered to the patient's heart within each respective tier of therapy.
(88) A battery **1858** provides operating power to all of the components in the IMD **1800**. The IMD **1800** further includes an impedance measuring circuit **1860**, which can be used for many things, including: lead impedance surveillance during the acute and chronic phases for proper lead positioning or dislodgement; detecting operable electrodes and automatically switching to an operable pair if dislodgement occurs; measuring thoracic impedance for determining shock thresholds; detecting when the device has been implanted; measuring stroke volume; and detecting the opening of heart valves; and so forth. The impedance measuring circuit **1860** is coupled to the switch **1892** so that any desired electrode may be used. The IMD **1800** can be operated as an implantable cardioverter/defibrillator (ICD) device, which detects the occurrence of an arrhythmia and automatically applies an appropriate electrical shock therapy to the heart aimed at terminating the detected arrhythmia. To this end, the microcontroller **1864** further controls a shocking circuit **1884** by way of a control signal **1886**.
(89) Closing
(90) It should be clearly understood that the various arrangements and processes broadly described and illustrated with respect to the Figures, and/or one or more individual components or elements of such arrangements and/or one or more process operations associated of such processes, can be employed independently from or together with one or more other components, elements and/or process operations described and illustrated herein. Accordingly, while various arrangements and processes are broadly contemplated, described and illustrated herein, it should be understood that they are provided merely in illustrative and non-restrictive fashion, and furthermore can be regarded as but mere examples of possible working environments in which one or more arrangements or processes may function or operate.
(91) As will be appreciated by one skilled in the art, various aspects may be embodied as a system, method, or computer (device) program product. Accordingly, aspects may take the form of an entirely hardware embodiment or an embodiment including hardware and software that may all generally be referred to herein as a “circuit,” “module” or “system.” Furthermore, aspects may take the form of a computer (device) program product embodied in one or more computer (device) readable storage medium(s) having computer (device) readable program code embodied thereon.
(92) Any combination of one or more non-signal computer (device) readable medium(s) may be utilized. The non-signal medium may be a storage medium. A storage medium may be, for example, an electronic, magnetic, optical, electromagnetic, infrared, or semiconductor system, apparatus, or device, or any suitable combination of the foregoing. More specific examples of a storage medium would include the following: a portable computer diskette, a hard disk, a random access memory (RAM), a dynamic random access memory (DRAM), a read-only memory (ROM), an erasable programmable read-only memory (EPROM or Flash memory), a portable compact disc read-only memory (CD-ROM), an optical storage device, a magnetic storage device, or any suitable combination of the foregoing.
(93) Program code for carrying out operations may be written in any combination of one or more programming languages. The program code may execute entirely on a single device, partly on a single device, as a stand-alone software package, partly on single device and partly on another device, or entirely on the other device. In some cases, the devices may be connected through any

type of network, including a local area network (LAN) or a wide area network (WAN), or the connection may be made through other devices (for example, through the Internet using an Internet Service Provider) or through a hard wire connection, such as over a USB connection. For example, a server having a first processor, a network interface, and a storage device for storing code may store the program code for carrying out the operations and provide this code through its network interface via a network to a second device having a second processor for execution of the code on the second device.

(94) Aspects are described herein with reference to the figures, which illustrate example methods, devices, and program products according to various example embodiments. The program instructions may be provided to a processor of a general-purpose computer, special purpose computer, or other programmable data processing device or information handling device to produce a machine, such that the instructions, which execute via a processor of the device implement the functions/acts specified. The program instructions may also be stored in a device readable medium that can direct a device to function in a particular manner, such that the instructions stored in the device readable medium produce an article of manufacture including instructions which implement the function/act specified. The program instructions may also be loaded onto a device to cause a series of operational steps to be performed on the device to produce a device implemented process such that the instructions which execute on the device provide processes for implementing the functions/acts specified.

(95) The units/modules/applications herein may include any processor-based or microprocessor-based system including systems using microcontrollers, reduced instruction set computers (RISC), application specific integrated circuits (ASICs), field-programmable gate arrays (FPGAs), logic circuits, and any other circuit or processor capable of executing the functions described herein. Additionally, or alternatively, the modules/controllers herein may represent circuit modules that may be implemented as hardware with associated instructions (for example, software stored on a tangible and non-transitory computer readable storage medium, such as a computer hard drive, ROM, RAM, or the like) that perform the operations described herein. The above examples are exemplary only, and are thus not intended to limit in any way the definition and/or meaning of the term “controller.” The units/modules/applications herein may execute a set of instructions that are stored in one or more storage elements, in order to process data. The storage elements may also store data or other information as desired or needed. The storage element may be in the form of an information source or a physical memory element within the modules/controllers herein. The set of instructions may include various commands that instruct the modules/applications herein to perform specific operations such as the methods and processes of the various embodiments of the subject matter described herein. The set of instructions may be in the form of a software program. The software may be in various forms such as system software or application software. Further, the software may be in the form of a collection of separate programs or modules, a program module within a larger program or a portion of a program module. The software also may include modular programming in the form of object-oriented programming. The processing of input data by the processing machine may be in response to user commands, or in response to results of previous processing, or in response to a request made by another processing machine.

(96) It is to be understood that the subject matter described herein is not limited in its application to the details of construction and the arrangement of components set forth in the description herein or illustrated in the drawings hereof. The subject matter described herein is capable of other embodiments and of being practiced or of being carried out in various ways. Also, it is to be understood that the phraseology and terminology used herein is for the purpose of description and should not be regarded as limiting. The use of “including,” “comprising,” or “having” and variations thereof herein is meant to encompass the items listed thereafter and equivalents thereof as well as additional items.

(97) It is to be understood that the above description is intended to be illustrative, and not

restrictive. For example, the above-described embodiments (and/or aspects thereof) may be used in combination with each other. In addition, many modifications may be made to adapt a particular situation or material to the teachings herein without departing from its scope. While the dimensions, types of materials and coatings described herein are intended to define various parameters, they are by no means limiting and are illustrative in nature. Many other embodiments will be apparent to those of skill in the art upon reviewing the above description. The scope of the embodiments should, therefore, be determined with reference to the appended claims, along with the full scope of equivalents to which such claims are entitled. In the appended claims, the terms “including” and “in which” are used as the plain-English equivalents of the respective terms “comprising” and “wherein.” Moreover, in the following claims, the terms “first,” “second,” and “third,” etc. are used merely as labels, and are not intended to impose numerical requirements on their objects or order of execution on their acts.

Claims

1. A capacitor for an implanted medical device, comprising: a capacitor stack including an anode layer, cathode layer, and electrolytic layer electrically coupled together, the capacitor stack including a capacitor stack periphery; a first cover portion having a first cover portion periphery that aligns with the capacitor stack periphery; and a metal case having a second cover portion periphery that aligns with the capacitor stack periphery and receives the first cover portion periphery to form a shell body for encasing the capacitor stack therein; wherein the capacitor stack includes a compressed anode portion and a compressed cathode portion that are coupled together at an end of the capacitor stack without the compressed anode portion or the compressed cathode portion engaging the first cover portion or the metal case such that the capacitor stack is isolated from the metal case to provide a neutrally charged metal case that is electrically coupled within the implanted medical device.
2. The capacitor of claim 1, wherein the first cover portion comprises an injection molded plastic.
3. The capacitor of claim 1, wherein the metal case comprises stainless steel.
4. The capacitor of claim 1, wherein the capacitor stack includes a first ferrule that is coupled with the compressed anode portion and extends through the shell body, and a second ferrule that is coupled with the compressed anode portion and extends through the shell body.
5. The capacitor of claim 4, wherein the compressed cathode portion includes a flat that that is welded to a wire assembly.
6. The capacitor of claim 1, wherein the capacitor stack periphery includes a first front that arcuately transitions to first input side that includes a first portion and a second portion angled from the first portion, the first input side arcuately transitioning to a first back that arcuately transitions into a first arcuate side that arcuately transitions into the first front.
7. The capacitor of claim 6, wherein the first cover portion periphery includes a second front that arcuately transitions to a second input side that includes a third portion and a fourth portion angled from the third portion, the second input side arcuately transitioning to a second back that arcuately transitions into a second arcuate side that arcuately transitions into the second front of the first cover portion periphery; and the second cover portion periphery includes a third front that arcuately transitions to a third input side that includes a fifth portion and a sixth portion angled from the third portion, the third input side arcuately transitioning to a third back that arcuately transitions into third arcuate side that arcuately transitions into the third front of the second cover portion periphery.
8. A capacitor for an implanted medical device, the capacitor comprising: a capacitor stack including an anode layer, cathode layer, and electrolytic layer electrically coupled together, the capacitor stack including a capacitor stack periphery; a plastic cover portion having a first cover portion periphery that aligns with the capacitor stack periphery; a metal cover portion having a

second cover portion periphery that aligns with the capacitor stack periphery and receives the first cover portion periphery to form a shell body for encasing the capacitor stack therein; wherein the capacitor stack includes a compressed anode portion and a compressed cathode portion that are coupled together at an end of the capacitor stack without the compressed anode portion or the compressed cathode portion engaging the plastic cover portion or the metal cover portion such that the capacitor stack is isolated from the metal cover portion to provide a neutrally charged metal cover portion that is electrically coupled within the implanted medical device.

9. The capacitor of claim 8, wherein the plastic cover portion comprises an injection molded plastic.

10. The capacitor of claim 8, wherein the metal cover portion comprises stainless steel.

11. The capacitor of claim 8, wherein the capacitor stack includes a first ferrule coupled with the compressed anode portion and that extends through the shell body, and a second ferrule coupled with the compressed cathode portion and that extends through the shell body.

12. The capacitor of claim 11, wherein the compressed cathode portion includes a flat that that is welded to a wire assembly.

13. The capacitor of claim 8, wherein the capacitor stack periphery includes a first front that arcuately transitions to a first input side that includes a first portion and a second portion angled from the first portion, and the input side arcuately transitions to a first back that arcuately transitions into a first arcuate side that arcuately transitions into the first front.

14. The capacitor of claim 13, wherein the first cover portion periphery includes a second front that arcuately transitions to a second input side that includes a third portion and a fourth portion angled from the third portion.

15. The capacitor of claim 14, wherein the second input side of the first cover periphery arcuately transitions to a second back that arcuately transitions into a second arcuate side that arcuately transitions into the second front of the first cover portion periphery.

16. The capacitor of claim 8, wherein the second cover portion periphery includes a front that arcuately transitions to an input side that includes a first portion and a second portion angled from the first portion.

17. The capacitor of claim 16, wherein the input side of the second cover portion periphery arcuately transitions to a back that arcuately transitions into an arcuate side that arcuately transitions into the front of the second cover portion periphery.