

Battery with integrated electronic module

5 The present disclosure relates to a battery with an integrated electronic module and to an implantable medical device comprising such battery.

Medical implant designs, particularly regarding pacemakers and cardioverter defibrillators, constantly evolve toward lower volume solutions. Design efforts aim towards a reduction of
10 the number of components, improved packing efficiency of the components, power reduction leading to reduced battery volume, or improved battery volumetric efficiency.

However, existing solutions for improving packing efficiency are limited by packing generally rectangular components into medical implant housings which tend toward rounded
15 designs. Also, the various components sometimes have different heights and must be placed on a substrate which provides mechanical stability and electrical connectivity. This all leads to packing inefficiency due to unused spaces left around the components.

Aspects of the invention are defined in the independent claims. Some optional features of
20 the invention are defined in the dependent claims.

Thus, it may be possible to provide an efficient design of a medical implant, particularly of its components, in which the number of components is reduced, the volume of the implant is more efficiently used and which enables a less laborious manufacturing.
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In one exemplary aspect, an implantable medical device is provided, which comprises a hermetic battery. The hermetic battery comprises

- 30 - a hermetically sealed battery housing defining an internal chamber,
- an electrochemical cell comprised within the internal chamber, and
- an electronic module comprised within the internal chamber.

The electronic module is electrically conductively connected to the electrochemical cell and the electronic module is arranged in said electrochemical cell.

- 5 The electronic module and the electrochemical cell may be non-hermetically separated from each other. The housing of the implantable medical device may be completely formed by the battery housing.

Advantageously, the number of components of the implantable medical device may be
10 significantly reduced in the medical device compared to common devices, since only one hermetically sealed housing and particularly only one hermetically sealed feedthrough are necessary. Accordingly, manufacturing may be significantly simplified.

In another exemplary aspect, an hermetic battery is provided, which comprises

- 15 - a hermetically sealed battery housing defining an internal chamber,
 - an electrochemical cell comprised within the internal chamber, and
 - an electronic module comprised within internal chamber,

The electronic module is electrically conductively connected to the electrochemical cell and the electronic module is arranged in the electrochemical cell.

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Particularly, it is envisioned that the electronic module is configured to generate an electric pulse, particularly a therapeutic electric pulse, and/or to determine a physiological parameter, particularly one or more physiological electric pulses, e.g. from the heart tissue of a patient, e.g. an electrocardiogram.

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In some embodiments of the implantable medical device, the electronic module may comprise a pulse generating unit being able to generate the (therapeutic) electric pulse.

In some embodiments of the implantable medical device or the hermetic battery, the
30 hermetically sealed battery housing comprises a hermetically sealed feedthrough, wherein the electronic module is electrically conductively connected to the feedthrough.

In some embodiments of the implantable medical device, the hermetically sealed battery housing may form at least partly, preferably completely, the housing of the implantable medical device.

5 Particularly, the battery housing and the feedthrough may be configured to hermetically seal the internal chamber, particularly such that substances of the battery do not leak out of the battery housing or that substances from outside of the housing do not leak into the battery housing. This may be achieved, for example, by a battery housing made of a metal or metal alloy, and a feedthrough comprising a metal flange, which is welded into a matching recess
10 or opening of the battery housing. Particularly, the feedthrough may comprise one or more electrically conductive connecting elements surrounded by an isolation body, respectively, which are fixed into matching openings in a metal flange, particularly by soldering, brazing or welding, which is in turn soldered, brazed or welded to the housing, thereby yielding a hermetically sealed feedthrough and a hermetically sealing battery housing. The battery
15 housing may be formed by two half shells welded together or by a housing beaker, for example a deep-drawn beaker, and a corresponding cover or lid welded together.

Typically, the feedthrough of an implantable medical device such as a pacemaker, a cardioverter defibrillator or neurostimulator may be connected to electrical contact elements
20 comprised in a so called header assembly, which provide a means to transmit electronic signals from the electronic module and/or the electrochemical cell via the feedthrough, particularly the connecting element, to a lead, which conducts the intended therapy. The header assembly, more specifically the electrical contact elements may be typically configured to receive a connector of the above mentioned lead.

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In some embodiments of the implantable medical device or the hermetic battery, the electrochemical cell may comprise at least a first electrolyte, wherein the electronic module may be in fluid communication with the at least first electrolyte.

30 In some embodiments of the implantable medical device or the hermetic battery, the battery housing may be made of a biocompatible material.

In some embodiments of the implantable medical device or the hermetic battery, the battery housing may be made of a biocompatible metal or metal alloy, and the electrochemical cell may be electrically isolated from the battery housing. Particularly, the battery housing may be made of titanium or a titanium alloy.

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In some embodiments of the implantable medical device or the hermetic battery, the electrochemical cell may be at least partly comprised within an envelope made of an electrically insulating material. Particularly, the electrically insulating material may be PEEK (polyether ether ketone, CAS Nr. 29658-26-2), POM (polyoxymethylene, CAS No. 9002-81-7), a parylene, a silicone or other polyimide based materials.

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In some embodiments of the implantable medical device or the hermetic battery, the electronic module may be at least partly, particularly completely, covered with a protective layer or embedded within a protective cover. The term “protective layer” or protective cover” in the context of the present specification particularly refers to a layer or cover that comprises a compound that is resistant or chemically inert to the condition of the electrochemical cell, particularly, resistant or chemically inert to an electrolyte comprised within the electrochemical cell.

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In some embodiments of the implantable medical device or the hermetic battery, the electronic module may be at least partly, particularly completely, covered with a parylene (a poly(p-xylylene) polymer). Non-limiting examples for a parylene include parylene C, parylene N, parylene D and parylene HT.

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In some embodiments of the implantable medical device or the hermetic battery, the electronic module may be at least partly, particularly complete, covered with or embedded within a liquid crystal polymer like poly(p-phenyleneterephthalamide (Kevlar), Vectran (a polycondensation product of 4-hydroxybenzoic acid and 6-hydroxynaphthalene-2-carboxylic acid) or Zenite (a liquid crystal polymer with glass fibre filler).

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In some embodiments of the implantable medical device or the hermetic battery, the electronic module may be at least partly, particularly complete, covered with or embedded

within an epoxy resin. Particular suitable epoxy resins may include, without being restricted to, Vitralit (which is a cationic one component epoxy resin curable by UV radiation) and Structalit (which can be a one or two component epoxy resin curable by heat), both also known as Glob-top casting compounds.

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In some embodiments of the implantable medical device or the hermetic battery, the electronic module may comprise one or more circuits, particularly one or more integrated circuits. Particularly, the electronic module may comprise a microprocessor and/or a storage component.

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In some embodiments of the implantable medical device or the hermetic battery, the electronic module may comprise a pulse generating unit or circuit, particularly a pacing unit or circuit and/or a shock unit or circuit, being able to generate the (therapeutic) electric pulse.

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In some embodiments of the implantable medical device or the hermetic battery, the electronic module, particularly the pacing unit or circuit, may be configured to provide a low voltage pulse, particularly a series of low voltage pulses, for example with a voltage in the range of 1.0 to 7.5 V.

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In some embodiments of the implantable medical device or the hermetic battery, the electronic module, particularly the shock unit or circuit, may be configured to provide a high voltage pulse, particularly with a voltage in the range of 100 to 1200 V. The electronic module may be connected to a capacitor, and the capacitor may be charged and discharged with the high voltage pulse, e.g. in the range of 100 to 1200 V.

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In some embodiments of the implantable medical device or the hermetic battery, the electronic module may further comprise a diagnostic unit or circuit, a telemetry unit or circuit and/or a charge control unit or circuit.

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In some embodiments of the implantable medical device or the hermetic battery, the electronic module may be configured to determine, particularly measure, one or more of the following physiological functions or parameters: electrocardiogram, electroencephalogram,

temperature, pressure, pH, acceleration, sound, a concentration of physiological compound or metabolite, e.g. glucose, oxygen, carbon dioxide or the like.

5 In some embodiments of the implantable medical device or the hermetic battery, the hermetic battery may further comprise at least one capacitor, wherein preferably the capacitor may be electrically connected to the electrochemical cell and/or the electronic module.

10 In some embodiments of the implantable medical device or the hermetic battery, the hermetic battery may be a primary battery or a secondary battery.

In some embodiments of the implantable medical device or the hermetic battery, the electronic module may comprise a self-test unit or circuit, wherein the self-test unit or circuit may be configured to conduct a burn-in test and/or a function test of the electronic module and, wherein the self-test module may be configured to transmit results of the burn-in test and/or the function test. Such burn-in test may be performed at an increased temperature and under defined load conditions including monitoring of electrical parameters like battery voltage, impedance, etc.

20 In some embodiments of the implantable medical device or the hermetic battery, the hermetically sealed battery housing may comprise a hermetically sealable opening. Advantageously, an electrolyte may be filled into the electrochemical cell via the hermetically sealable opening. After filling the electrolyte into the electrochemical cell, the hermetically sealable opening may be hermetically sealed, e.g. by welding.

25 Accordingly in some embodiments of the implantable medical or the hermetic battery, the electrochemical cell may comprise at least a first cathode and at least a first anode, but not an electrolyte.

30 In some embodiments of the implantable medical device or the hermetic battery, the electrochemical cell may comprise at least a first anode made of a material consisting of or

comprising, but not being restricted to, lithium, a graphites, a hard carbon, a meso-carbon, silicon, and/or lithium-titanate.

5 In some embodiments of the implantable medical device or the hermetic battery, the electrochemical cell may comprise at least a first cathode made of a material consisting of or comprising, but not being restricted to, a manganese oxide, a vanadium oxide, a carbon monofluoride, a lithium cobalt oxide or a mixed metal oxide.

10 In some embodiments of the implantable medical device or the hermetic battery, the electrochemical cell may comprise at least a first electrolyte consisting of or comprising, but not being restricted to, a non-aqueous or aqueous solvent with dissolved salts, particularly dissolved salts of lithium like lithium perchlorate, lithium hexafluorophosphate, lithium hexafluoroarsenate or lithium tetrafluoroborate.

15 In some embodiments of the implantable medical device or the hermetic battery, the electronic module may at least partly electrically isolate the electrochemical cell from the battery housing, wherein particularly the electronic module may be arranged between the electrochemical cell and the feedthrough.

20 In some embodiments of the implantable medical device or the hermetic battery, the electronic module may comprise a power-on unit, which is configured to control a defined start up procedure during filling the electrolyte into the battery. Advantageously, the hermetic battery or the implantable medical device may be premanufactured and stored without consumption of the battery charge. Such power-unit may be formed by a
25 management circuitry, which monitors the battery voltage and manages the power on of the complete system by using voltage regulators etc.

In some embodiments of the implantable medical device, the device further may comprise a connector assembly being electrically conductively connected to the hermetically sealed
30 feedthrough outside of the hermetically sealed battery housing, particularly to one or more connecting elements of the hermetically sealing feedthrough. Particularly, such connector may comprise two or more electrical connecting elements, such as, for example, a spring

sleeve or an annular member with a in there fixed spring element or a socket, that are configured to conductively connect a connector of a lead received by the connector assembly to the hermetically feedthrough and ultimately to the electronic module and the electrochemical cell. This may be facilitated by ribbons welded to the connecting element of the feedthrough and the connecting element of the connector assembly. Particularly, the connector assembly may comprise two, four or eight connecting elements. Typically, a biocompatible resin, commonly an epoxy resin, may be then casted around the connector assembly.

In some embodiments of the implantable medical device, the implant may comprise a capacitor, particularly a by-pass capacitor, comprised within the internal chamber. Particularly, the capacitor, particularly the by-pass capacitor, may be encased or embedded in aluminium oxide, e. g, sapphire.

Accordingly in an embodiment, an integrated circuit or other components, substantially hermetically sealed, may be placed within an electrochemical cell, where some components previously realized as discrete components may be now realized on the integrated circuit. Accordingly, as many components as possible are transferred onto or arranged on the silicon die of the controlling integrated circuit. The integrated circuit is preferably encased in aluminum oxide (sapphire) and placed within the electrolyte of the electrochemical cell thus eliminating useless volume between components. A bypass capacitor could also be placed in the cell to improved high frequency current demand. Also, an antenna coil in the form of an insulated platinum coil could be located within the cell. Remaining components would have to be located outside the cell, requiring feedthrough connections so these would have to be minimized.

Advantageously, a volumetric efficiency improvement from incorporating small capacitors on an integrated circuit (IC) may be possible because they have very low profile on an integrated circuit, and by placing the integrated circuit within the cell chemistry, all volume around the IC may be efficiently used to increase the capacity of the cell. This embodiment works best for cases of a lone signal leaving the integrated circuit through a feedthrough.

According to an alternative embodiment, an integrated circuit and other low profile components may be contained in a low profile ceramic package, which is then placed within an electrochemical cell, wherein the ceramic package may provide electrical feedthrough to the exterior of the cell. Particularly, a ceramic substrate with a cavity and lid to contain low profile components may be utilized within the electrochemical cell and provide a hermetic enclosure. An extension of this substrate would contain conductors on inner layers and pass through a glass frit or other sealing mechanism to act as a feedthrough to exit the cells interior. Necessary external components could be placed on this feedthrough exterior to the cell.

Advantageously, the disclosed feedthrough technique may solve electrical isolation issues associated with signals leaving the IC. The second embodiment is less limited.

Further advantages, features and embodiments will be explained hereinafter by way of example only and with reference to the figures, in which:

Fig. 1 a schematic drawing of an implantable cardioverter defibrillator according to the prior art;

Fig. 2 shows an embodiment of the implantable device, and

Fig. 3 shows an alternative embodiment of the implantable device.

Generally, the present disclosure aims towards limiting the number of external components and using the entire volume around the limited components to increase the storage capacity of the electrochemical cell of a battery.

Figure 1 illustrates the design of a conventional implantable active medical device such as a pacemaker (IPG) 100. The pacemaker comprises a first hermetically closed housing 110 made of biocompatible material (commonly case titanium or a titanium alloy), in which comprises a battery 120, an electronic module 130 and electric through-connections comprised within via a hermetically sealing feedthrough, which are designed to connect the

electronic module 130 with one or more components outside of the closed housing 110 commonly known as the header of the pacemaker (not shown in Figure 1). Such header usually comprises one or more connector assemblies that are configured to receive one or more leads of the pacemaker. The battery 120 comprises a second hermetically sealed battery housing 121 to protect the electronic module 130 from the interior of the battery 120, i.e. the environment or the electrolyte within the battery, respectively. The electric connection between the battery and the electronic module is realized by two battery terminals 131, 132. Those terminal 131, 132 likewise are guided out of the battery housing 121 via a feedthrough.

Figure 2 shows the more convenient, improved pacemaker design 200. The pacemaker 200 comprises a single hermetically sealed biocompatible housing 210, in which the components of the battery 220 (anode, cathode, electrolyte) are accommodated and additionally the electronic module 230. The electronic module 230 is preferably coated, for example with a parylene, to protect the electronic module 230 from the condition present inside the battery. The electronic module 230 is connected inside the battery connected to the power or voltage supply via an electrical connection 240. For connecting the electronic module 230 with the outer components of the pacemaker, i.e. the lead via the header, a terminal of the electronic module 230, e.g. a stimulating terminal, is guided through the housing 220 by a hermetically sealed feedthrough 250.

By the design, the engineering effort is significantly reduced, particularly since only one hermetically sealed housing and one hermetically sealed feedthrough are needed. Advantageously, the above described designed is applicable for any implantable medical device, such as a cardiac monitors, or active implants besides pacemakers such as neurostimulators or cardioverter defibrillators.

Figure 3 shows another design comprising a battery with integrated electronic module. The depicted active implant 300 comprises a housing 310 or housing beaker made of titanium that is hermetically sealable with a cover element 320 of the housing. An encapsulated electronic module 330 is integrated in the housing 310 such that it is sufficiently protected against the conditions present within the housing. The electronic module 330 is equipped

with or connected to a feedthrough 340, by which one or more terminals for leads, sensors, antenna, etc., may be electrically guide through the cover element 320 in a hermetically tight manner. Typically, such feedthrough 340 comprise one or more connecting elements such as conductive pin that are isolated from a flange or the cover element by an insulating
5 element such as glass, ceramic or a polymer such as an epoxy resin.

Also the electrodes 360 of the battery (i. e. the electrode package including anodes, cathodes and separators, etc.) are integrated into the housing 310 and insulated from housing 310 or housing beaker by an insulating envelope. Advantageously, insulating the electrodes 360
10 against the cover element 320 can be constructively realized by the electronic module 330, particularly by arranging the electronic module between the electrodes 350 and the cover element 320 as illustrated in Figure 3. Additionally, the electronic module 330 is used to electrically interconnect the common arrestors of the electrodes, respectively.

15 For filling the housing 310 with an appropriate electrolyte, the cover element may comprise an opening through which the electrolyte may be filled into the housing and which will be hermetically closed after filling. To enable the flow of the electrolyte, the electronic module 330 is designed shorter than the front side 370 of the electrode package 360.

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Claims

1. An implantable medical device (200, 300) comprising a hermetic battery (120),
wherein said hermetic battery comprises:
 - 5 - a hermetically sealed battery housing (210, 310, 320) defining an internal chamber,
 - an electrochemical cell (220, 350) comprised within said internal chamber, and
 - an electronic module (230, 330) comprised within said internal chamber, wherein
10 said electronic module (230, 330) is configured to generate a therapeutic electric pulse, and/or to determine a physiological parameter, particularly a physiological electric pulse,
wherein said electronic module (230, 330) is electrically conductively connected to
said electrochemical cell (220), and
said electronic module (230, 330) is arranged in said electrochemical cell (220, 350).
- 15 2. The implantable medical device (200, 300) according to claim 1, wherein said battery housing (210, 310, 320) is made of a biocompatible material.
3. The implantable medical device (200, 300) according to claim 1 or 2, wherein said
20 battery housing (210, 310, 320) is made of a biocompatible metal or metal alloy, particularly comprising or consisting of titanium, and said electrochemical cell is electrically isolated from said battery housing.
4. The implantable medical device (200, 300) according to any one of the preceding
25 claims, wherein said electrochemical cell (220, 350) is at least partly comprised within an envelope (360) made of an electrically isolating material, particularly selected from PEEK, POM, a parylene or other polyimide based materials.
5. The implantable medical device (200, 300) according to any one of the preceding
30 claims, wherein said electronic module (230, 330) is at least partly, particularly completely, covered by a protective layer or embedded within a protective cover.

6. The implantable medical device (200, 300) according to any one of the preceding claims, wherein said electronic module (230, 330) comprises one or more circuits, particularly one or more integrated circuits, more particular a microprocessor and/or a storage component.
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7. The implantable medical device (200, 300) according to any one of the preceding claims, wherein said electronic module (230, 330) comprises a pulse generating unit, particularly a pacing unit and/or a shock unit, being able to generate said therapeutic electric pulse.
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8. The implantable medical device (200, 300) according to claim 6 or 7, wherein
- said electronic module (230, 330), particularly said pacing unit, is configured to provide a low voltage pulse, particularly a series of low voltage pulses, for example with a voltage in the range of 1.0 to 7.5 V, and/or
 - 15 - said electronic module (230, 330), particularly the shock unit, is configured to provide a high voltage pulse, particularly with a voltage in the range of 100 to 1200 V.
9. The implantable medical device (200, 300) according to any one of the preceding claims, wherein said electronic module (230, 330) comprises a diagnostic unit, a telemetry unit and/or a charge control unit.
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10. The implantable medical device (200, 300) according to any one of the preceding claims, wherein said hermetic battery (120) further comprises at least one capacitor.
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11. The implantable medical device (200, 300) according to any one of the preceding claims, wherein said electronic module (230, 330) comprises a self-test module, wherein said self-test module is configured to conduct a burn-in test and/or a function test of said electronic module and, wherein said self-test module is further configured
- 30 to transmit results of said burn-in test and/or said function test.

12. The implantable medical device (200, 300) according to any one of the preceding claims, wherein said battery housing (210, 310) comprises a hermetically sealable opening (380).
- 5 13. The implantable medical device (220, 300) according to any one of the preceding claims, wherein said electrochemical cell (220, 350) comprises
- at least a first anode essentially consisting of or comprising lithium, graphites, hard carbon, meso-carbons, silicium, and/or lithium-titanate; and/or
 - at least a first cathode essentially consisting of or comprising a manganese oxide,
10 a vanadium oxide, a carbon monofluoride, a lithium cobalt oxide or a mixed metal oxide; and/or
 - an electrolyte essentially consisting of or comprising a non-aqueous or aqueous solvent with dissolved salts like lithium perchlorate, lithium hexafluorophosphate, lithium hexafluoroarsenate or lithium tetrafluoroborate.
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14. The implantable medical device (200, 300) according to any one of the preceding claims, wherein said electronic module (230, 330) at least partly electrically isolates said electrochemical cell (220, 350) from said battery housing (210, 310, 320), wherein particularly said electronic module (230, 330) is arranged between said
20 electrochemical cell (220, 350) and a feedthrough (250, 340).