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EMI Filter Feedthrough Having A Single-Sided Oxide-Resistant System Ground Opposite A System Ground To An Oxidized Surface

Abstract

A filtered feedthrough comprises an insulator sealed in a ferrule opening. A terminal pin sealed in an insulator via hole has a first end that extends outwardly beyond an insulator device side. A filter capacitor has a square- or rectangularly-shaped dielectric supporting interleaved active and ground electrode plates. A passageway extending through the dielectric has an internal metallization. An external metallization is contacted to opposed longitudinal sides of the dielectric outer surface. The capacitor ground electrode plates extend to the opposed external metallizations. The outwardly extending terminal pin end is connected to the internal metallization in the dielectric passageway which in turn is connected to the active electrode plates. A conductive material connects the capacitor external metallization at one of the longitudinal sides to an oxide-resistant surface on the ferrule while the other external metallization is connected to an oxidized surface of the ferrule.

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Background/Summary

CROSS-REFERENCE TO RELATED APPLICATIONS [0001] This application is a continuation-in-part of U.S. patent application Ser. No. 18/921,348, filed on Oct. 21, 2024, now U.S. Pat. No. ______, which claims priority to U.S. provisional patent application Ser. No. 63/595,511, filed on Nov. 2, 2023.

BACKGROUND OF THE INVENTION
1. Field of the Invention
[0002] The present invention generally relates to both implantable and externally worn active medical devices that include a hermetic electromagnetic (EMI) filter feedthrough assembly. More particularly, the present invention relates to an EMI filter feedthrough capacitor, preferably having a rectangular shape, that is grounded to an oxide-resistant surface on only one of its long sides. The opposed long side of the filter feedthrough capacitor is grounded to an oxidized surface. A single-sided oxide-resistant system ground opposite an oxidized system ground for a filter capacitor helps to reduce the complexity and cost associated with building an EMI filter feedthrough assembly, among other benefits. For an asymmetrical hermetically-sealed EMI filter feedthrough assembly relative to the longitudinal axis of its ferrule, a single-sided oxide-resistant system ground opposite a system ground to an oxidized ferrule surface increases the EMI feedthrough capacitor size (width) which makes its design electrically more conservative thereby improving production yields, reliability, and safety factor without unduly sacrificing EMI attenuation afforded by the filter capacitor.
[0003] The term “active” is defined as a medical device that includes a power source so that the medical device can deliver an electrical stimulation pulse to body tissue, receive sensed biologic signal from body tissue, or both stimulate and sense.
2. Prior Art
[0004] Turning now to the drawings, FIG. **1** is a wire form diagram of a generic human body that is intended to give context to the wide range of active implantable and externally worn medical devices that incorporate a filter feedthrough assembly for attenuation of electromagnetic interference (EMI).
[0005] Numerical designation **100**A represents a family of hearing devices which can include the group of cochlear implants, piezoelectric sound bridge transducers, and the like.
[0006] Numerical designation **100**B represents a variety of neurostimulators, brain stimulators, and brain sensors. Neurostimulators are used to stimulate the Vagus nerve, for example, to treat epilepsy, obesity, and depression. Brain stimulators are pacemaker-like devices and include electrodes implanted deep into the brain for sensing the onset of a seizure and also for providing electrical stimulation to brain tissue to prevent a seizure from actually occurring. Sensors include optical sensors, motion sensors, acoustic sensors, pressure sensors, analyte sensors, and electromagnetic sensors, among others.
[0007] Numerical designation **100**C shows a cardiac pacemaker which is well-known in the art. Cardiac pacemakers include cardiac pacemakers with transvenous leads, leadless pacemakers, and cardiac resynchronization pacemakers, also known as CRT-P devices.
[0008] Numerical designation **100**D includes the family of left ventricular assist devices (LVADs)

and artificial heart devices.
[0009] Numerical designation **100**E includes a family of drug pumps, which can be used for dispensing insulin, chemotherapy drugs, pain medications, and the like.
[0010] Numerical designation **100**F includes a variety of bone growth stimulators for rapid healing of fractures.
[0011] Numerical designation **100**G includes urinary incontinence devices.
[0012] Numerical designation **100**H includes the family of pain relief spinal cord stimulators and anti-tremor stimulators. Numerical designation **100**H also includes an entire family of other types of neurostimulators used to block pain.
[0013] Numerical designation **100**I includes both implantable cardioverter defibrillator (ICD) devices and congestive heart failure devices (CHF). These are known in the art as cardio resynchronization therapy devices, otherwise known as CRT-D devices.
[0014] Numerical designation **100**J illustrates an externally worn pack. The pack can be an external insulin pump, an external drug pump, an external neurostimulator or even a ventricular assist device.
[0015] Numerical designation **100**K illustrates one of various types of EKG/ECG external skin electrodes which can be placed at various external locations on the body.
[0016] Numerical designation **100**L represents external EEG electrodes that are placed on the head.
[0017] In that respect, active medical devices, both implantable and externally worn, have evolved over time to include higher and higher lead counts. For example, in the early days of pacemakers, only the right ventricle was paced. However, design improvements led to dual chamber pacing where the right ventricle and the right atrium are paced. This required two bipolar leads connected to four hermetically-sealed feedthrough terminal pins.
[0018] As illustrated is the side cutaway view of a prior art cardiac pacemaker **100**C system shown in FIG. **2**, with only four terminal pins, it was practical to manufacture round quad-polar filtered hermetic seals or filter feedthrough assemblies. The pacemaker electronics reside inside a hermetically sealed active implantable medical device (AIMD) housing **116** (typically made from titanium), which provides an electrically conductive electromagnetic shield. The header block **101** is typically made from a thermosetting insulating plastic or compound, such as Tecothane®, and houses one or more connector assemblies, generally in accordance with ISO Standards IS-1, IS-2, IS4 or DF4. The header block connector ports (female connectors) are labelled **103**, **103′**. Implantable leads **107**, **107′** have proximal plugs **105**, **105′** (male connectors), which are designed to be inserted into and mate with the female header block connector ports **103**, **103′**.
[0019] Further regarding FIG. **2**, the system ground **124** comprises the conductive housing **116**, which, as noted above, provides the overall electromagnetic shield, and also functions as an energy dissipating surface. The cardiac pacemaker also has a hermetically sealed feedthrough **120** to which a round quad-polar EMI filter capacitor **132** is mounted. Since the conductive ferrule **112** (typically made from titanium) of the feedthrough **120** is electrically connected to the medical device housing **116**, the ferrule **112** is also part of the system ground **124**. Accordingly, the system ground **124** illustrated in FIG. **2** includes the ferrule **112** and the device housing **116**.
[0020] Still referring to FIG. **2**, the electrical connection of the EMI filter capacitor **132** to the system ground **124** is better appreciated. When the external ground metallization **142***a* (better shown in FIGS. **3** and **3**A for a rectangularly-shaped capacitor) of the EMI filter capacitor **132** is electrically connected to the ferrule **112** of the hermetically sealed feedthrough **120**, and the ferrule **112** in turn is hermetically sealed (typically by welding, such as laser welding) to the conductive device housing **116** of the exemplary medical device, for example, a cardiac pacemaker **100**C, then the external ground metallization **142***a* is electrically connected to the system ground **124**. FIG. **3**A shows the external ground metallization **142***a* contacting a gold braze **150** and a continuous gold pad **165** supported on a ferrule **112**. The braze **150** seals the ferrule **112** to a metallization **151** on an outer peripheral surface of the feedthrough insulator **160** and contacts a gold pad **165** supported on

a device side surface of the ferrule **112**. The braze **150** and extended gold pad **165** are formed from one contiguous gold braze at the same time. Exemplary gold pads are shown in FIGS. 21 and 22 of U.S. Pat. No. 6,765,779 to Stevenson et al. The '779 patent is assigned to the assignee of the present invention and incorporated herein by reference.

[0021] As schematically depicted in FIG. **3**B, an EMI filter capacitor **132** is a three-terminal device in that there is an input side (terminal circle **1**), an output side (terminal circle **2**) and a ground (terminal three). It is well known that an implanted lead can undesirably act as an antenna and couple to high frequency electromagnetic interference (EMI) energy. This EMI energy may be undesirably coupled along the implanted leads **107**, **107**′ (FIG. **2**), which is then directed to sensitive electronics **140** contained inside the device housing **116**. It is well known that EMI can disrupt the proper operation of the electronic circuitry **140**. Thus, the function of the feedthrough capacitor **132** illustrated in FIGS. **2** and **3** is to couple to incoming EMI energy in the implanted lead and divert it to the electromagnetically shielded device housing **116** comprising the equipotential system ground **124** where the EMI energy will be dissipated as a harmless amount of thermal or RF energy.

[0022] In other words, it is the job of feedthrough capacitor **132** to protect the sensitive electronics **140** while at the same time freely allowing pacing or therapeutic pulses to pass and also to allow the device electronics **140** to sense biological signals that are generally in the frequency range from zero to 2000 Hz without interruption. The capacitor **132** is also known as a frequency variable impedance element. The capacitive reactance X.sub.c in ohms: X.sub.c=1/[2πfc]. This inverse relationship with frequency means that at very low frequencies, the capacitor **132** acts as an open circuit (as if it were not there at all). At very high frequencies, the capacitor **132** substantially acts as a short circuit where it diverts undesirable RF energy such as emissions from cellular telephones, microwave ovens, and the like, to the system ground **124**. In that manner, dangerous EMI energy is prevented from entering the device housing **116** where it could reach the sensitive electronic circuitry **140** and seriously disrupt the proper operation of any one of the above-described medical devices **100**A to **100**L. Such EMI disruption could inadvertently suspend therapy, which, depending on the medical device, could be immediately life threatening.

[0023] It is also within the scope of the exemplary cardiac pacemaker **100**C system shown in FIG. **2** (or any of the other medical devices depicted in FIG. **1**) that the ferrule **112** can be a continuous part of the device housing **116**. This means that the ground metallization **142***a*, the ferrule **112**, the gold braze/contact pad **165** (FIGS. **3** and **3**A) and the medical device housing **116** are all at the same potential; they are all at ground potential and are all part of the overall active medical device equipotential surface (in other words, system ground **124**). Since the hermetically sealed enclosure of the medical device blocks EMI from entering inside the device housing **116**, it is commonly known as an EMI shield or a Faraday cage.

[0024] However, modern cardiac implantable electronic devices (CIEDs) provide therapeutic pacing and biologic signal sensing to chambers in both the right and left sides of the heart. These are known as cardiac resynchronization devices. CRT-P devices are cardiac resynchronization therapy-pacemaker devices. CRT-D devices are cardiac resynchronization therapy-defibrillator devices. These resynchronization devices have hermetic feedthroughs with more than four terminal pins, for example, 8, 11, 13, 16, and more terminal pins. Neurostimulators, such as spinal cord stimulators, generally have greater than 25 terminal pins and possibly as many as 35 terminal pins.

[0025] For patient comfort, for example, in the pectoral pocket, it is very important that a filter feedthrough assembly is as thin as possible. However, as the number of hermetically-sealed feedthrough terminal pins that are connectable to associated implantable leads has increased over time, a round or square hermetic seal geometry is no longer desirable or practical. Round, high terminal pin count filter feedthrough assemblies are much too large in diameter for acceptable patient comfort. For that reason, most present-day EMI filter capacitors for hermetic feedthroughs are rectangular with the terminal pins aligned inline or in dual inline configurations to achieve both the required high terminal pin count and the desired device thinness.

[0026] Turning now to FIGS. **3**, **3**A and **3**B, these drawings illustrate an exemplary conventional or prior art rectangularly-shaped EMI filter feedthrough assembly **210** having inline terminal pins. The filter feedthrough assembly **210** comprises an electrically conductive ferrule **112** having a ferrule opening extending to spaced-apart ferrule device and body fluid sides. Preferably, the ferrule **112** has a rectangular shape so that in a plan view, looking at either of the ferrule device or body fluid side, the ferrule comprises opposed ferrule first and second longitudinal sidewalls **112**A and **112**B that extend to and meet with opposed ferrule third and fourth end walls **112**C and **112**D. The longitudinal sidewalls **112**A, **112**B are longer than the end walls **112**C, **112**D and are aligned substantially parallel to and on opposite sides of a ferrule center line (FIG. **3**A) that intersects the opposed third and fourth end walls **112**C, **112**D.

[0027] The filter feedthrough assembly **210** further comprises an electrically non-conductive insulator **160**, preferably made from alumina, having an insulator outer surface that extends to spaced-apart insulator device and body fluid sides. The insulator **160** is hermetically secured to the ferrule **112** in the ferrule opening by a first gold braze **150** that seals around the perimeter of the insulator. That way, when the ferrule **112** hermetically sealed to the insulator **160** is attached to an opening in a housing of any one of the above-described medical devices **100**A to **100**L, the ferrule and insulator body fluid sides, and the opposed ferrule and insulator device sides reside outside and inside the medical device, respectively.

[0028] Further, at least two, and preferably a plurality of, insulator via holes **126** extend to the insulator device and body fluid sides. Respective outer and inner insulator metallizations **151**, **153** are disposed on the perimeter outer surface and in the via holes **126** of the insulator. These metallizations **151**, **153** can be applied by sputtering, electroplating, physical vapor deposition or glass frit metallization bonding, and may comprise titanium, molybdenum, niobium, silver, copper, platinum, palladium, platinum silver, palladium silver, and combinations thereof.

[0029] A respective one of at least two, and preferably a plurality of, terminal pins (FIG. **3** shows an exemplary number of terminal pins **111**_a_, **111**_b_, **111**_c_ and **111**_d_) reside in one of the insulator via holes **126** where a second gold braze **162** hermetically seals the terminal pin to the inner metallization **153** contacted to the insulator **160** in the via hole **126**. The terminal pins **111**_a_, **111**_b_, **111**_c_ and **111**_d_ extend to first and second ends with at least the terminal pin first ends extending outwardly beyond the insulator device side.

[0030] The filter feedthrough assembly **210** further comprises a filter feedthrough capacitor **132** that is mounted adjacent to the insulator device side of the feedthrough **120**. The filter capacitor **132** has a rectangularly-shaped or square-shaped, preferably rectangularly-shaped, dielectric **122** supporting interleaved active and ground electrode plates **146** and **148**. A plurality of inline passageways **143** extend through the dielectric **122**. Each passageway **143** has an internal metallization **144**. The metallized inline passageways **143** are electrically connected to the active electrode plates **146** but not to the ground electrode plates **148**. An insulative washer **212** extending across the bottom of the EMI filter capacitor **132** rests on top of the device side of the ferrule **112** hermetically sealed to the insulator **160**.

[0031] The rectangularly-shaped feedthrough capacitor dielectric **122** has opposed relatively long longitudinal sides **122**A and **122**B that extend to and meet with relatively short ends **122**C and **122**D. External metallizations **142**_a_ and **142**_b_ are contacted to the respective longitudinal sides **122**A and **122**B of the capacitor dielectric **122**. If desired, the opposed short ends **122**C, **122**D can also be terminated, but that is optional.

[0032] The ground electrode plates **148** extend to the external metallizations **142**_a_, **142**_b_ at the terminated longitudinal sides **122**A, **122**B of the dielectric **122**. The outwardly extending ends of a corresponding number of the inline terminal pins **111**_a_, **111**_b_, **111**_c_ and **111**_d_ comprising the feedthrough **120** are received in the dielectric passageways **143** where they are connected to the internal metallization **144** by an inner electrically conductive material **156**. The inner conductive material **156** electrically connects the metallized dielectric passageways **143** to the interleaved active electrode plates **146**.

[0033] An outer conductive material **152** electrically connects the capacitor external metallizations **142***a*, **142***b* at the opposed terminated longitudinal sides **122**A, **122**B of the rectangularly-shaped dielectric **122** to a gold braze **150** that hermetically connects the insulator outer perimeter metallization **151** to the ferrule **112** comprising the previously described system ground **124**. A gold contact pad **165** is shown as a continuous body with the braze **150**.

[0034] As shown in FIGS. **3** and **3**A, to provide a larger oxide-resistant electrical connection, an oxide-resistant material **165**, preferably gold, in the form of a contact pad is supported on the device side surface of the ferrule **112** adjacent to the gold braze **150**. Preferably, the outer conductive material **152** is contacted to both the gold braze **150** and to the gold contact pad **165** to provide a desirably very low impedance and very low resistance electrical connection. Suitable outer conductive materials **152** include a solder, a thermosetting electrically conductive adhesive, an electrically conductive silicone, a braze, an electrically conductive polyimide, an electrically conductive epoxy, and the like.

[0035] However, there have been efforts to improve the insertion loss or filter attenuation of the filter feedthrough assembly **210** illustrated in FIGS. **3**, **3**A and **3**B to meet the needed performance requirements for both MRI compatibility and compatibility with industry standard ISO14117. That is because connecting to the perimeter gold braze **150** hermetically sealing between the outer metallization **151** on the perimeter of the insulator **160** and the ferrule **112** in the ferrule opening can result in the filter capacitor **132** having a truncated lateral extent. The gold contact pad **165** located immediately adjacent to the gold braze **150** helps to widen the lateral extent of the low impedance and low resistance electrical connection between the ground electrode plates **148** and the ground metallizations **142***a*, the ferrule **112** and the medical device housing **116** comprising the system ground **124**. However, providing an oxide-resistant contact pad **165** adjacent to both ground metallizations **142***a* and **142***b* represents an added expense in gold that could be avoided with a redesigned filter feedthrough.

[0036] Accordingly, there is a need for a redesigned filter feedthrough assembly where the ground electrode plates of the filter capacitor are attached to a system ground in a low impedance and low resistance electrical connection, but that also considers the added expense attributed to providing gold contact pads adjacent to both of the longitudinal sidewalls of a rectangularly-shaped capacitor. Moreover, it is desirable to have the filter capacitor provide as much effective capacitance as a particular filter feedthrough assembly will afford.

SUMMARY OF THE INVENTION

[0037] The present invention relates to a hermetically sealed EMI filter feedthrough assembly for an active medical device that can be both implantable and intended to be worn externally. The novel active medical device comprises a feedthrough connected to an EMI filter capacitor, preferably with the capacitor having a square or rectangular shape, and with the filter capacitor only being terminated to an oxide-resistant system ground on one of its longitudinal sides. The opposed longitudinal side of the filter capacitor is terminated to an oxidized surface of the ferrule for the feedthrough. This opposite side oxidized connection considers the added expense attributed to providing gold contact pads adjacent to both of the longitudinal sidewalls of a rectangularly-shaped capacitor. Additionally, an opposite side oxidized connection helps stabilize the filter capacitor by preventing the capacitor from wobbling or rocking on the ferrule and insulator of the feedthrough.

[0038] Wobbling and rocking are particularly concerning when the filter capacitor is subjected to a high voltage surge such as occurs when an electrical pulse of several hundred volts passes through the capacitor during a cardiac defibrillation event, and the like. The resulting piezioelectric stress high voltage surge could cause the ceramic feedthrough capacitor to expand and contract which, if one side of the capacitor was not attached to the ferrule, could result in wobbling and rocking.

Therefore, the present EMI filter capacitor having one side connected to an oxide-resistant system ground opposite a system ground to an oxidized surface offers a number of important manufacturing and cost reduction advantages as compared to the prior art EMI filter capacitor designs. Accordingly, this is a single sided low impedance system ground with a double-sided mechanical connection.

[0039] More particularly, the present invention relates to a hermetically sealed filtered feedthrough for an active medical device (AMD). In one embodiment, the filtered feedthrough comprises an electrically conductive ferrule having a ferrule opening extending to spaced-apart ferrule device and body fluid sides. The device side portions of the ferrule without a gold braze has an oxidized/oxidizable layer which can impede filter performance.

[0040] Preferably, the ferrule has a rectangular shape so that in a plan view looking at either of the ferrule device side or body fluid side, the ferrule comprises opposed ferrule first and second longitudinal side walls that extend to and meet with opposed ferrule third and fourth end walls with the longitudinal side walls being longer than the end walls. The first and second longitudinal side walls are aligned parallel to and on opposite sides of a ferrule center line that intersects the opposed third and fourth end walls.

[0041] Further, an electrically non-conductive insulator has an insulator outer surface that extends to spaced-apart insulator device and body fluid sides. The insulator disposed in the ferrule opening is hermetically sealed to the ferrule by a first gold braze so that when the ferrule hermetically sealed to the insulator is attached to an opening in a housing of an AMD, the ferrule and insulator body fluid sides, and the corresponding ferrule and insulator device sides reside outside and inside the AMD, respectively.

[0042] Still further, at least two insulator via holes extending to the insulator device and body fluid sides reside between the insulator second longitudinal side wall and the ferrule center line, and an insulator metallization is disposed on the insulator outer surface and in the insulator via holes. A respective one of at least two terminal pins reside in one of the insulator via holes where a second gold braze hermetically seals the terminal pin to the insulator. The terminal pins extend to terminal pin first and second ends with at least the terminal pin first ends extending outwardly beyond the insulator device side. That way, the at least two terminal pins reside between the insulator second longitudinal side wall and the ferrule center line.

[0043] The filtered feedthrough also comprises a filter feedthrough capacitor that is disposed at or adjacent to the insulator device side. The capacitor comprises a dielectric outer surface extending to a dielectric first major face spaced from a dielectric second major face. At least one active electrode plate and at least one ground electrode plate are supported in the capacitor dielectric in an interleaved, partially overlapping capacitive relationship. Then, at least two dielectric passageways extend to the dielectric first and second major faces and a capacitor internal metallization is disposed in the dielectric passageways. The at least one active electrode plate is connected to the capacitor internal metallization in the dielectric passageways, and the outwardly extending terminal pin first ends reside in a respective one of the dielectric passageways where the terminal pin is conductively connected to the capacitor internal metallization connected to the at least one active electrode plate by a first conductive material. Moreover, the at least one ground electrode plate is in a non-conductive relation with the capacitor internal metallization in the dielectric passageway.

[0044] A capacitor external metallization is disposed on a terminated first dielectric outer surface portion and on a spaced-apart terminated second dielectric outer surface portion of the dielectric outer surface. The at least one ground electrode plate is conductively connected to the capacitor external metallization at the terminated first and second dielectric outer surface portions with the at least one active electrode plate being in a non-conductive relation with the capacitor external metallization. A second conductive material connects the capacitor external metallization at the terminated first dielectric outer surface portion to the first gold braze sealing the insulator to the ferrule or to a gold bond pad supported on the ferrule device side, and a third conductive material connects the capacitor external metallization at the terminated second dielectric outer surface portion to the oxide layer on the ferrule device side.

[0045] These and other objects of the present invention will become increasingly more apparent to those skilled in the art by reference to the following description and to the appended drawings.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

[0046] FIG. **1** is a wire formed diagram of a generic human body showing a number of medical devices **100**A to **100**L according to the present invention that can either be implanted in a patient's body tissue or attached externally to the body.

[0047] FIG. **2** is a side cutaway view of a prior art cardiac pacemaker **100**C system.

[0048] FIG. **3** is a perspective view of an inline quad-polar EMI filter feedthrough assembly **210** according to the prior art.

[0049] FIG. **3**A is a cross-sectional view taken along line **3**A-**3**A of FIG. **3**.

[0050] FIG. **3**B is the electrical schematic of the quad-polar EMI filter capacitor shown in FIGS. **3** and **3**A.

[0051] FIG. **4** is a perspective view of an inline quad-polar EMI filter feedthrough assembly **210**A similar to that shown in FIG. **3** but with the back- or right-side **122**B of the EMI filter capacitor **132**A not being connected to an oxide-resistant ground on the ferrule **112** of the feedthrough **120**.

[0052] FIG. **4**A is a cross-sectional view taken along line **4**A-**4**A of FIG. **4**.

[0053] FIG. **4**B is a cross-sectional view taken along line **4**B-**4**B of FIG. **4**.

[0054] FIG. **4**C is the electrical schematic of the quad-polar EMI filter capacitor shown in FIGS. **4**, **4**A and **4**B.

[0055] FIG. **5** is a perspective view of an inline quad-polar EMI filter feedthrough assembly **210**B similar to that shown in FIG. **4** but with the front- or left-side **122**A of the EMI filter capacitor **132**B being connected to an oxide-resistant ground on the ferrule **112** and with the back- or right-side **122**B of the filter capacitor **132**B being connected to an oxidized surface of the ferrule **112** for the feedthrough **120**.

[0056] FIG. **5**A is a cross-sectional view taken along line **5**A-**5**A of FIG. **5** showing the terminal pins **111** being offset with respect to the center line of the ferrule and hermetic seal.

[0057] FIG. **5**B is a cross-sectional view taken along a ground electrode plate **148** for the filter feedthrough assembly **210**B similar to that shown in FIG. **5** but with the terminal pins **111***a* to **111***j* being offset closer to the back- or right-side **122**B of the filter capacitor **132**B connected to an oxidized surface of the ferrule **112** than to the front- or left-side **122**A of the EMI filter capacitor **132**B connected to an oxide-resistant ground on the ferrule **112** for the feedthrough **120**.

[0058] FIG. **6** is a cross-sectional view of an EMI filter feedthrough assembly **210**C similar to the EMI filter feedthrough assembly **210**B shown in FIGS. **5**, **5**A and **5**B except that the capacitor dielectric **122** supports dual active and ground electrode plates **146**, **148**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0059] Turning now to FIGS. **4** and **4**A to **4**C, these drawings illustrate an exemplary rectangularly-shaped EMI filter feedthrough assembly **210**A having inline terminal pins as described in U.S. patent application Ser. No. 18/921,348, filed on Oct. 21, 2024, which is assigned to the assignee of the present invention and incorporated herein by reference. The filter feedthrough assembly **210**A comprises an electrically conductive ferrule **112** having a ferrule opening extending to spaced-apart ferrule device and body fluid sides. Preferably, the ferrule **112** has a rectangular shape so that in a plan view, looking at either of the ferrule device or body fluid side, the ferrule comprises opposed ferrule first and second longitudinal sidewalls **112**A and **112**B that extend to and meet with opposed ferrule third and fourth end walls **112**C and **112**D. The longitudinal sidewalls **112**A, **112**B are longer than the end walls **112**C, **112**D and are aligned parallel to and on opposite sides of a ferrule center line (FIG. **4**A) that intersects the opposed third and fourth end walls **112**C, **112**D.

[0060] The filter feedthrough assembly **210**A further comprises an electrically non-conductive insulator **160**, preferably made from alumina, having an insulator outer surface that extends to spaced-apart insulator device and body fluid sides. The insulator **160** is hermetically secured to the ferrule **112** in the ferrule opening by a first gold braze **150** that seals around the perimeter of the insulator. That way, when the ferrule **112** hermetically sealed to the insulator **160** is attached to an opening in a housing of any one of the above-described medical devices **100**A to **100**L, the ferrule and insulator body fluid sides, and the opposed ferrule and insulator device sides reside outside and inside the medical device, respectively.

[0061] Further, at least two, and preferably a plurality of, insulator via holes **126** extend to the insulator device and body fluid sides. Respective outer and inner insulator metallizations **151**, **153** are disposed on the insulator outer surface and in the insulator via holes **126**. These metallizations **151**, **153** can be applied by sputtering, electroplating, physical vapor deposition or glass frit metallization bonding, and may comprise titanium, molybdenum, niobium, silver, copper, platinum, palladium, platinum silver, palladium silver, and combinations thereof.

[0062] A respective one of at least two, and preferably a plurality of, terminal pins (FIG. **4** shows an exemplary number of terminal pins **111***a*, **111***b*, **111***c* and **111***d*, known as a quadpolar filter) reside in one of the insulator via holes **126** where a second gold braze **162** hermetically seals the terminal pin to the inner metallization **153** contacted to the insulator **160** in the via hole **126**. The terminal pins **111***a*, **111***b*, **111***c* and **111***d* extend to first and second ends with at least the terminal pin first ends extending outwardly beyond the insulator device side. The terminal pins reside between the ferrule second longitudinal sidewall **112**B and the ferrule center line.

[0063] The filter feedthrough assembly **210**A further comprises a filter capacitor **132**A that is mounted adjacent to the insulator device side of the feedthrough **120**. The filter capacitor **132**A has a rectangularly-shaped or square-shaped, preferably rectangularly-shaped, dielectric **122** comprising an outer surface extending to a dielectric first major face spaced from a dielectric second major face. The capacitor dielectric **122** supports interleaved active and ground electrode plates **146** and **148**. A plurality of inline passageways **143** extend through the dielectric **122**. Each passageway **143** has an internal metallization **144**. The metallized inline passageways **143** are electrically connected to the active electrode plates **146** but not to the ground electrode plates **148**. An insulative washer **212** extending across the bottom of the EMI filter capacitor **132**A rests on top of the device side of the ferrule **112** hermetically sealed to the insulator **160**.

[0064] The rectangularly-shaped capacitor dielectric **122** has opposed relatively long longitudinal sides **122**A and **122**B that extend to and meet with relatively short ends **122**C and **122**D. An external metallization **142***a* is contacted to a terminated longitudinal side **122**A but not to the opposite, unterminated longitudinal side **122**B of the capacitor dielectric **122**.

[0065] If desired, the opposed short ends **122**C, **122**D can also be terminated, but that is optional. In that case, the terminal pins and the ferrule are not centered between the longitudinal sides **122**A and **122**B of the capacitor dielectric **122**. Instead, to increase capacitor design efficiency, the capacitor width is increased without increasing the overall size of the ferrule/hermetic seal, the terminal pins are deliberately offset toward the short side **122**D. Effective capacitance area (ECA) is increased, which allows for a more conservative electrical design with improved capacitor reliability and production yields.

[0066] The ground electrode plates **148** extend to the external metallization **142***a* at the terminated longitudinal side **122**A, but they do not extend to the opposed, unterminated longitudinal side **122**B of the dielectric **122**. The outwardly extending ends of a corresponding number of the inline terminal pins **111***a*, **111***b*, **111***c* and **111***d* comprising the feedthrough **120** are received in the dielectric passageways **143** where they are connected to the internal metallization **144** by an inner electrically conductive material **156**. The inner conductive material **156** connects the metallized

dielectric passageways **143** to the interleaved active electrode plates **146**.
[0067] An outer conductive material **152** connects the capacitor external metallization **142***a* at the terminated longitudinal side **122**A of the rectangularly-shaped dielectric **122** to a gold braze **150** that hermetically connects the insulator outer metallization **151** to the ferrule **112** comprising the previously described system ground **124**. Contacting the outer conductive material **152** to the gold braze **150** provides a desirably very low impedance and very low resistance electrical connection. Suitable outer conductive materials **152** include a solder, a thermosetting electrically conductive adhesive, an electrically conductive silicone, a braze, an electrically conductive polyimide, an electrically conductive epoxy, and the like.
[0068] Calculations using PSpice and Microsim have demonstrated that there is sufficient insertion loss or filter attenuation to meet the needed performance requirements for MRI compatibility and compatibility with industry standard ISO14117 for all implantable cardiac electronic devices with only one side of a rectangularly-shaped EMI filter capacitor being connected to an oxide-resistant system ground, as shown in the filter feedthrough assembly illustrated in FIGS. **4** and **4**A to **4**C.
[0069] However, there is a desire to further improve the stability of the filter feedthrough assembly illustrated in FIGS. **3** and **3**A without adding too much extra cost. That is because wobbling and rocking of the EMI filter capacitor mounted to the device side of the feedthrough **120** are particularly concerning when the filter capacitor is subjected to a high voltage surge and piezoelectric stress such as occurs when an electrical pulse of several hundred volts passes through the capacitor during a cardiac defibrillation event, and the like.
[0070] Turning now to FIGS. **5**, **5**A and **5**B, a filter feedthrough assembly **210**B according to the present invention is illustrated. The filter feedthrough assembly **210**B comprises a filter capacitor **132**B having one side electrically connected to an oxide-resistant system ground (gold braze **150**) opposite a system ground to an oxidized surface. Not only does this construction offers a number of important manufacturing and cost reduction advantages as compared to the filter feedthrough assembly **210**A illustrated in FIGS. **4** and **4**A to **4**C but connecting the opposite side **122**B of the capacitor dielectric **122** to an oxidized surface of the ferrule **112** helps to mechanically stabilize the filter capacitor by preventing the capacitor from wobbling or rocking on the feedthrough, particularly during a high voltage discharge event. In that respect, an electrically conductive connection **152** is made to the gold braze **150** adjacent to side **122**A but also to the oxidized ferrule surface on the **122**B side. The oxidized surface on the **122**B side still allows for some reduced filter performance, but this is a positive, not a negative (something is better than nothing). The downside is that additional expense is incurred by adding ground metallization **142***b* connected to capacitor ground electrode plates **148**.
[0071] In particular, the FIGS. **5**, **5**A and **5**B illustrate an exemplary rectangularly-shaped EMI filter feedthrough assembly **210**B comprising an electrically conductive ferrule **112** having a ferrule opening extending to spaced-apart ferrule device and body fluid sides. Preferably, the ferrule **112** has a rectangular shape so that in a plan view, looking at either of the ferrule device or body fluid side, the ferrule comprises opposed ferrule first and second longitudinal sidewalls **112**A and **112**B that extend to and meet with opposed ferrule third and fourth end walls **112**C and **112**D with the longitudinal sidewalls **112**A, **112**B being longer than the end walls **112**C, **112**D. The first and second longitudinal sidewalls **112**A, **112**B are aligned parallel to and on opposite sides of a ferrule center line that intersects the opposed third and fourth end walls **112**C, **112**D.
[0072] The filter feedthrough assembly **210**B further comprises an electrically non-conductive insulator **160**, preferably made from alumina, having an insulator outer surface that extends to spaced-apart insulator device and body fluid sides. The insulator **160** is hermetically sealed to the ferrule **112** in the ferrule opening by a first gold braze **150** that seals around the perimeter of the insulator. That way, when the ferrule **112** hermetically sealed to the insulator **160** is attached to an opening in a housing of any one of the above-described medical devices **100**A to **100**L, the ferrule and insulator body fluid sides, and the opposed ferrule and insulator device sides reside outside and

inside the medical device, respectively.

[0073] Further, at least two, and preferably a plurality of, insulator via holes **126** extend to the insulator device and body fluid sides. Respective insulator outer and inner metallizations **151**, **153** are disposed on the insulator outer surface and in the insulator via holes **126**. These metallizations **151**, **153** can be applied by sputtering, electroplating, physical vapor deposition or glass frit metallization bonding, and may comprise titanium, molybdenum, niobium, silver, copper, platinum, palladium, platinum silver, palladium silver, and combinations thereof.

[0074] A respective one of at least two, and preferably a plurality of, terminal pins (FIG. **5** shows an exemplary number of terminal pins **11***a*, **11***b*, **11***c* and **111***d* while FIG. **5**B shows ten exemplary terminal pins **111***a* to **111***j*) reside in one of the insulator via holes **126** where a second gold braze **162** hermetically seals the terminal pin to the inner metallization **153** contacted to the insulator **160** in the via hole. The terminal pins **111***a* to **111***d* or **111***a* to **111***j* extend to terminal pin first and second ends with at least the terminal pin first ends extending outwardly beyond the insulator device side.

[0075] The filter feedthrough assembly **210**B further comprises the filter capacitor **132**B that is mounted adjacent to the insulator device side of the feedthrough **120** and that comprises a rectangularly-shaped or square-shaped, preferably rectangularly-shaped, dielectric **122** supporting interleaved active and ground electrode plates **146** and **148**. A plurality of inline passageways **143** extend through the dielectric **122**. Each of the inline passageways **143** has an internal metallization **144**. The metallized inline passageways **143** are electrically connected to the active electrode plates **146** but not to the ground electrode plates **148**. An insulative washer **212** extending across the bottom of the EMI filter capacitor **132**B rests on top of the device side of the ferrule **112** hermetically sealed to the insulator **160**.

[0076] The rectangularly-shaped dielectric **122** has opposed relatively long longitudinal sides **122**A and **122**B that extend to and meet with relatively short ends **122**C and **122**D. Respective external metallizations **142***a*, **142***b* are contacted to the opposed terminated longitudinal sides **122**A and **122**B of the capacitor dielectric **122**. Desirably, the opposed short ends **122**C, **122**D are not terminated. In the alternative, the opposed short ends **122**C, **122**D can be terminated, but little in filter performance is gained at added expense.

[0077] The ground electrode plates **148** extend to the external metallization **142***a* at the longitudinal side **122**A and to the external metallization **142***b* at the opposed longitudinal side **122**B of the dielectric **122**. The outwardly extending ends of a corresponding number of the inline terminal pins **111***a* to **111***d* or **111***a* to **111***j* comprising the feedthrough **120** are received in the dielectric passageways **143** where they are connected to the internal metallization **144** by an inner electrically conductive material **156**. The inner conductive material **156** connects the metallized dielectric passageways **143** to the interleaved active electrode plates **146**.

[0078] An outer conductive material **152** connects the capacitor external metallization **142***a* at the terminated longitudinal side **122**A of the rectangularly-shaped dielectric **122** to a gold braze **150** that hermetically connects the insulator outer metallization **151** to the ferrule **112** comprising the previously described system ground **124**. If desired, an oxide-resistant material **165**, preferably gold, in the form of a contact pad is supported on the device side surface of the ferrule **112** adjacent to the gold braze **150**. The contact pad **165** can be continuous with the gold braze **150** or the braze **150** and pad **165** can be spaced from each other by a portion of the ferrule **112** (FIG. **5**A). Preferably, the outer conductive material **152** is contacted to the gold braze **150** and, if present, to the gold contact pad **165** to provide a desirably very low impedance and very low resistance electrical connection.

[0079] As previously described, the ferrule **112** is preferably made from titanium. Titanium has excellent corrosion resistance and biocompatibility. However, in the presence of human body fluids, the excellent corrosion resistance exhibited by titanium is due to the formation of a thermodynamically stable, continuous, highly adherent, and protective surface oxide film. Since titanium metal is highly reactive and has an extremely high affinity for oxygen, this surface oxide film is formed spontaneously and instantly when a fresh titanium metal surface is exposed to air and moisture (even at room temperature). Unfortunately, the titanium oxide layer acts as an insulator that impedes proper filter bypass performance.

[0080] Nonetheless, for improved stability of the EMI filter capacitor mounted to the feedthrough **120**, the outer conductive material **152** also connects the capacitor external metallization **142***b* at the terminated longitudinal side **122**B of the rectangularly-shaped dielectric **122** to the device side surface of the ferrule **112**. Since gold is a relatively expensive material, this connection of the capacitor external metallization **142***b* at the terminated longitudinal side **122**B is spaced outwardly from the gold braze **150** that hermetically connects the insulator outer metallization **151** to the ferrule **112** comprising the previously described system ground **124**. However, to save the added expense of an oxide-resistant connection adjacent to the terminated longitudinal side **122**B of the rectangularly-shaped dielectric **122**, a gold contact pad is not provided adjacent to the capacitor external metallization **142***b*. Again, suitable outer conductive materials **152** for connection to both capacitor metallizations **142***a*, **142***b* include a solder, a thermosetting electrically conductive adhesive, an electrically conductive silicone, a braze, an electrically conductive polyimide, an electrically conductive epoxy, and the like.

[0081] While this embodiment of an EMI filter feedthrough assembly **210**B according to the present invention does not exhibit the same level of insertion loss or filter attenuation as is exhibited by the filter feedthrough assembly **210** illustrated in FIGS. **3**, **3**A and **3**B and by the filter feedthrough assembly **210**A illustrated in FIGS. **4** and **4**A to **4**C, calculations using PSpice and Microsim and insertion loss measurements in dB have demonstrated that there is sufficient insertion loss or filter attenuation to meet the needed performance requirements for MRI compatibility for the various medical devices **100**A to **100**L described above.

[0082] Moreover, for improved structural integrity, it is an aspect of the filter feedthrough assembly **210**B according to the present invention that the opposed terminated longitudinal side **122**B of an EMI filter capacitor, preferably a square-shaped or rectangularly-shaped capacitor, is connected to the oxidized device side surface of the ferrule. Since contacting an oxide-resistant material, for example, gold, to the device side surface of the ferrule adjacent to the both of the longitudinal sides **122**A and **122**B of the capacitor dielectric **122** represents an additional expense in gold as a noble precious metal, according to the present invention, only one of the longitudinal sides **122**A or **122**B is contacted to an oxide-resistant surface. The other of the sides **122**A and **122**B in not contacted to an oxide resistant surface. While not optimum, the improved structural integrity for the filter feedthrough assembly **210**B is a viable tradeoff.

[0083] In that respect, for a square-shaped or rectangularly-shaped filter capacitor, the longitudinal side of the capacitor that is opposite the terminated longitudinal side connected to the oxide-resistant gold braze, and optionally to the gold pad **165**, on the device side surface of the ferrule is also connected to the ferrule **112**, but this side of the ferrule has an oxidized surface at the connection. In other words, according to the present invention, it is not necessary that this opposed ground termination is connected to a low impedance non-oxidizable surface, such as gold.

[0084] The filter feedthrough assembly **210**C illustrated FIG. **6** is similar to the assembly **210***b* shown in FIG. **5** except that the active and ground electrode plates **146** and **148** now occur in electrode plate pairs. These are known as dual electrodes. Dual electrodes are thoroughly described in U.S. Pat. No. 5,978,204 (Ex Parte Reexamination Certificate 4920.sup.th), which is assigned to the assignee of the present invention and herein fully incorporated by reference. In the present invention, dual electrodes are very important in that the electrode total conductive area is greatly increased. This more than makes up for the ground **142***b* on the right-hand side of the filtered filter capacitor being directly connected to an oxidized surface of the ferrule **112**. The dual electrodes have a very low equivalent series resistance and a very low impedance across the width of the feedthrough filter capacitor **132**C. It is therefore a preferred embodiment of the present invention

that the electrodes be in dual electrode pairs.
[0085] One might ask why not three or four electrodes in parallel, and the answer is that no more than dual electrodes will work. The addition of a third electrode between a pair of dual electrodes would do nothing since there is no electric field between the third electrode and its adjacent electrode plates.
[0086] Thus, the present invention relates to a filter feedthrough assembly comprising a square- or rectangularly-shaped EMI filter capacitor. The feedthrough comprises an insulator sealed in a ferrule opening. A terminal pin sealed in an insulator via hole has a first end that extends outwardly beyond an insulator device side. The square- or rectangularly-shaped EMI filter capacitor is positioned adjacent to the insulator device side and comprises a dielectric supporting interleaved active and ground electrode plates. At least one passageway extending through the dielectric has an internal metallization. An external metallization is contacted to the opposed longitudinal sides of the square- or rectangularly-shaped capacitor dielectric. The capacitor ground electrode plates extend to the external metallizations at the terminated longitudinal sides. The outwardly extending terminal pin end is connected to the internal metallization in the dielectric passageway which in turn is connected to the active electrode plates. A conductive material connects the external metallization contacted to one of the longitudinal sides to an oxide-resistant material supported on the device side of the ferrule while the external metallization contacted to the other longitudinal side of the capacitor dielectric is connected to an oxidized surface of the ferrule.
[0087] It is appreciated that various modifications to the inventive concepts described herein may be apparent to those skilled in the art without departing from the spirit and scope of the present invention as defined by the hereinafter appended claims.

Claims

1. A hermetically sealed EMI filtered feedthrough for an active medical device (AMD), the EMI filtered feedthrough comprising: a) an electrically conductive ferrule comprising a ferrule opening extending to a ferrule device side spaced from a ferrule body fluid side; b) an electrically non-conductive insulator comprising an insulator outer surface extending to an insulator device side spaced from an insulator body fluid side, wherein the insulator is hermetically sealed to the ferrule in the ferrule opening by a first gold braze so that when the ferrule is attached to an opening in a housing of an AMD, the ferrule and insulator body fluid sides, and the ferrule and insulator device sides reside outside and inside the AMD, respectively, and wherein at least two insulator via holes extend to the insulator device and body fluid sides; c) an insulator internal metallization disposed in the at least two insulator via holes; d) first and second terminal pins residing in a respective one of the at least two insulator via holes where a second gold braze hermetically seals the terminal pin to the insulator internal metallization, wherein the first and second terminal pins extend to first and second terminal pin first ends spaced from first and second terminal pin second ends, and wherein at least the first and second terminal pin first ends extend outwardly beyond the insulator device side; e) a filter capacitor disposed at or adjacent to the insulator device side, the filter capacitor comprising: i) a capacitor dielectric comprising a dielectric outer surface extending to a dielectric first major face spaced from a dielectric second major face; ii) at least one active electrode plate and at least one ground electrode plate supported in the capacitor dielectric in an interleaved, partially overlapping capacitive relationship; iii) first and second dielectric passageways extending into the capacitor dielectric from the dielectric first major face adjacent to the insulator device side; iv) a capacitor internal metallization disposed in the first and second dielectric passageways and being conductively connected to the at least one active electrode plate, wherein the outwardly extending first and second terminal pin first ends reside in the respective first and second dielectric passageways where the terminal pins are conductively connected to the capacitor internal metallization connected to the at least one active electrode plate by a first conductive material; and

v) a capacitor external metallization disposed on a terminated first dielectric outer surface portion and on a spaced-apart terminated second dielectric outer surface portion of the dielectric outer surface, wherein the at least one ground electrode plate is conductively connected to the capacitor external metallization at the terminated first and second dielectric outer surface portions; and f) a second conductive material connecting the capacitor external metallization at the terminated first dielectric outer surface portion to the first gold braze sealing the insulator to the ferrule; and g) a third conductive material connecting the capacitor external metallization at the terminated second dielectric outer surface portion to the ferrule device side.

2. The EMI feedthrough filter of claim 1, wherein the ferrule is made of titanium and at least a portion of the ferrule device side has an exposed layer of titanium oxide, and wherein the third conductive material connects the capacitor external metallization at the terminated second dielectric outer surface portion to the exposed layer of titanium oxide on the ferrule device side.

3. The EMI feedthrough filter of claim 1, wherein spaced-apart unterminated third and fourth dielectric outer surface portions of the capacitor dielectric reside between and electrically isolate the terminated first and second dielectric outer surface portions from each other.

4. The EMI feedthrough filter of claim 3, wherein, in a plan view looking at the dielectric first major face, the capacitor dielectric has a rectangular shape comprising opposed dielectric first and second long sides extending to and meeting with opposed dielectric third and fourth short ends, and wherein the at least one ground electrode plate extends to the dielectric first and second long sides comprising the spaced-apart terminated first and second dielectric outer surface portions, but the ground electrode plate does not extend to the dielectric third and fourth short ends comprising the unterminated third and fourth dielectric outer surface portions of the capacitor dielectric.

5. The EMI feedthrough filter of claim 3, wherein, in a plan view looking at the dielectric first major face, the capacitor dielectric has a square shape comprising opposed dielectric first and second sides extending to and meeting with opposed dielectric third and fourth sides, the dielectric first and second sides being substantially equal in length to the dielectric third and fourth sides, and wherein the at least one ground electrode plate extends to the spaced-apart dielectric first and second sides comprising the spaced-apart terminated first and second dielectric outer surface portions, but the ground electrode plate does not extend to the dielectric third and fourth sides comprising the unterminated third and fourth dielectric outer surface portions of the capacitor dielectric.

6. The EMI feedthrough filter of claim 1, wherein, in a plan view looking at the ferrule device side: a) the ferrule has a rectangular shape comprising ferrule first and second longitudinal side walls that extend to and meet with opposed ferrule third and fourth end walls, wherein the ferrule first and second longitudinal side walls are aligned parallel to and on opposite sides of a ferrule center line that bisects the opposed ferrule third and fourth end walls; b) the insulator hermetically sealed to the ferrule in the ferrule opening has opposed insulator first and second longitudinal side walls that extend to and meet with opposed insulator third and fourth end walls so that the shape of the insulator matches the shape of the ferrule opening; and c) the first and second terminal pins residing in a respective one of the at least two insulator via holes reside between the insulator second longitudinal side wall and the ferrule center line.

7. The EMI feedthrough filter of claim 6, wherein the first and second terminal pins residing in a respective one of the at least two insulator via holes are aligned parallel to the insulator second longitudinal side wall and the ferrule center line.

8. The EMI feedthrough filter of claim 1, wherein the first conductive material conductively connecting the outwardly extending first and second terminal pin first ends to the capacitor internal metallization connected to the at least one active electrode plate, the second conductive material connecting the capacitor external metallization at the terminated first dielectric outer surface portion to at least one of the first gold braze or the gold bond pad supported on the ferrule device side, and the third conductive material connecting the capacitor external metallization at the terminated second dielectric outer surface portion to the ferrule device side are individually selected from the group of a solder, a thermosetting electrically conductive adhesive, an electrically conductive silicone, a braze, an electrically conductive polyimide, and an electrically conductive epoxy.

9. The EMI feedthrough filter of claim 1, wherein the at least one active electrode plate comprises a closely-spaced pair of active electrode plates and the at least one ground electrode plate comprises a closely-spaced pair of ground electrode plates.

10. The EMI feedthrough filter of claim 1, wherein an insulative washer is disposed between the insulator and the filter capacitor.

11. The EMI feedthrough filter of claim 1, wherein the ferrule is configured to be attachable to a housing of an active e medical device by a laser weld.

12. The EMI feedthrough filter of claim 1, wherein the ferrule is a continuous part of an active medical device housing.

13. The EMI feedthrough filter of claim 1, further comprising a gold bond pad supported on the ferrule device side, wherein the second conductive material connects the capacitor external metallization at the terminated first dielectric outer surface portion to at least one of the first gold braze sealing the insulator to the ferrule and the gold bond pad supported on the ferrule device side.

14. A hermetically sealed EMI filtered feedthrough for an active medical device (AMD), the EMI filtered feedthrough comprising: a) a titanium ferrule comprising a ferrule opening extending to a ferrule device side spaced from a ferrule body fluid side, wherein at least a portion of the ferrule device side has an exposed layer of titanium oxide; b) an electrically non-conductive insulator comprising an insulator outer surface extending to an insulator device side spaced from an insulator body fluid side, wherein the insulator is hermetically sealed to the ferrule in the ferrule opening by a first gold braze so that when the ferrule is attached to an opening in a housing of an AMD, the ferrule and insulator body fluid sides, and the ferrule and insulator device sides reside outside and inside the AMD, respectively, and wherein at least two insulator via holes extend to the insulator device and body fluid sides; c) an insulator internal metallization disposed in the at least two insulator via holes; d) first and second terminal pins residing in a respective one of the at least two insulator via holes where a second gold braze hermetically seals the terminal pin to the insulator internal metallization, wherein the first and second terminal pins extend to first and second terminal pin first ends spaced from first and second terminal pin second ends, and wherein at least the first and second terminal pin first ends extend outwardly beyond the insulator device side; e) a filter capacitor disposed at or adjacent to the insulator device side, the filter capacitor comprising: i) a capacitor dielectric comprising a dielectric outer surface extending to a dielectric first major face spaced from a dielectric second major face; ii) at least one active electrode plate and at least one ground electrode plate supported in the capacitor dielectric in an interleaved, partially overlapping capacitive relationship; iii) first and second dielectric passageways extending into the capacitor dielectric from the dielectric first major face adjacent to the insulator device side; iv) a capacitor internal metallization disposed in the first and second dielectric passageways and being conductively connected to the at least one active electrode plate, wherein the outwardly extending first and second terminal pin first ends reside in the respective first and second dielectric passageways where the terminal pins are conductively connected to the capacitor internal metallization connected to the at least one active electrode plate by a first conductive material; and v) a capacitor external metallization disposed on a terminated first dielectric outer surface portion and on a spaced-apart terminated second dielectric outer surface portion of the dielectric outer surface, wherein the terminated first dielectric outer surface portion resides spaced above the first gold braze hermetically sealing the insulator to the ferrule, and the terminated second dielectric outer surface portion extends laterally outwardly beyond the first gold braze, and wherein the at least one ground electrode plate is conductively connected to the capacitor external metallization at the terminated first and second dielectric outer surface portions; and f) a second conductive material connecting the capacitor external metallization at the terminated first dielectric outer surface portion to the first gold braze sealing the insulator to the ferrule or a gold bond pad supported on the ferrule device side; and g) a third conductive material connecting the capacitor external metallization at the terminated second dielectric outer surface portion to the exposed layer of titanium oxide on the ferrule device side, spaced laterally outwardly beyond the first gold braze.

15. The EMI feedthrough filter of claim 14, wherein: a) the ferrule comprises opposed ferrule first and second longitudinal side walls that extend to and meet with opposed ferrule third and fourth end walls, the ferrule first and second longitudinal side walls being aligned parallel to and on opposite sides of a ferrule center line that bisects the opposed ferrule third and fourth end walls; b) the insulator hermetically sealed to the ferrule in the ferrule opening has opposed insulator first and second longitudinal side walls that extend to and meet with opposed insulator third and fourth end walls with the at least two insulator via holes residing between the insulator second longitudinal side wall and the ferrule center line; c) the filter capacitor has a rectangular shape so that in a plan view looking at the dielectric first major face, opposed dielectric first and second long sides extend to and meet with opposed dielectric third and fourth short ends; d) the at least one ground electrode plate is conductively connected to the capacitor external metallization disposed on the dielectric first and second long sides as the terminated first and second dielectric outer surface portions; e) the dielectric first long side resides spaced above the first gold braze or the gold bond pad supported on the ferrule device side, and the dielectric second long side extends laterally outwardly beyond the first gold braze; and f) the second conductive material conductively connects the capacitor external metallization at the dielectric first long side serving as the terminated first dielectric outer surface portion to at least one of the first gold braze or the gold bond pad and the third conductive material conductively connects the capacitor external metallization at the terminated second dielectric outer surface portion to the exposed layer of titanium oxide on the ferrule device side, spaced laterally outwardly beyond the first gold braze.

16. The EMI feedthrough filter of claim 14, further comprising a gold bond pad supported on the ferrule device side, wherein the second conductive material connects the capacitor external metallization at the terminated first dielectric outer surface portion to at least one of the first gold braze sealing the insulator to the ferrule and the gold bond pad supported on the ferrule device side.

17. A hermetically sealed EMI filtered feedthrough for an active implantable medical device (AMD), the EMI filtered feedthrough comprising: a) a titanium ferrule comprising a ferrule opening extending to a ferrule device side spaced from a ferrule body fluid side, wherein at least a portion of the ferrule device side has an exposed layer of titanium oxide; b) an electrically non-conductive insulator comprising an insulator outer surface extending to an insulator device side spaced from an insulator body fluid side, wherein the insulator disposed in the ferrule opening is hermetically sealed to the ferrule by a first gold braze so that when the ferrule is attached to an opening in a housing of an AMD, the ferrule and insulator body fluid sides, and the ferrule and insulator device sides reside outside and inside the AMD, respectively, and wherein at least one insulator via hole extends to the insulator device and body fluid sides; c) an insulator internal metallization disposed in the insulator via hole; d) a terminal pin residing in the insulator via hole where a second gold braze hermetically seals the terminal pin to the insulator internal metallization, wherein the terminal pin extends to a terminal pin first end spaced from a terminal pin second end, and wherein at least the terminal pin first end extends outwardly beyond the insulator device side; e) a filter capacitor disposed at or adjacent to the insulator device side, the filter capacitor comprising: i) a capacitor dielectric comprising a dielectric outer surface extending to a dielectric first major face spaced from a dielectric second major face; ii) at least one active electrode plate and at least one ground electrode plate supported in the capacitor dielectric in an interleaved, partially overlapping capacitive relationship; iii) a dielectric passageway extending into the capacitor dielectric from the dielectric first major face adjacent to the insulator device side; iv) a capacitor internal metallization disposed in the dielectric passageway and being conductively connected to the at least one active electrode plate, wherein the outwardly extending terminal pin first end resides in the dielectric passageway where the terminal pin is conductively connected to the capacitor internal metallization connected to the at least one active electrode plate by a first conductive material; and v) a capacitor external metallization disposed on at least a first portion and a spaced-apart second portion of the dielectric outer surface to provide terminated first and second dielectric outer surface portions that are separated from each other by intermediate and unterminated third and fourth dielectric outer surface portions, wherein the at least one ground electrode plate extends to the terminated first and second dielectric outer surface portions, and the at least one ground electrode plate either does or does not extend to the unterminated third and fourth dielectric outer surface portions; and f) a second conductive material connecting the terminated first portion of the capacitor external metallization to the first gold braze sealing the insulator to the ferrule or to a gold bond pad supported on the ferrule device side; and g) a third conductive material connecting the terminated second portion of the capacitor external metallization to the exposed layer of titanium oxide on the ferrule device side, spaced laterally outwardly beyond the first gold braze.

18. The EMI feedthrough filter of claim 17, wherein, in a plan view looking at the dielectric first major face, the capacitor dielectric has a rectangular shape comprising opposed dielectric first and second long sides extending to and meeting with opposed dielectric third and fourth short ends, and wherein the at least one ground electrode plate extends to the dielectric first and second long sides comprising the spaced-apart terminated first and second dielectric outer surface portions, but the ground electrode plate does not extend to the dielectric third and fourth short ends comprising the unterminated third and fourth dielectric outer surface portions of the capacitor dielectric.

19. The EMI feedthrough filter of claim 17, further comprising a gold bond pad supported on the ferrule device side, wherein the second conductive material connects the capacitor external metallization at the terminated first dielectric outer surface portion to at least one of the first gold braze sealing the insulator to the ferrule and the gold bond pad supported on the ferrule device side.