METHOD OF FORMING FEEDTHROUGH WITH INTEGRATED BRAZELESS FERRULE

Background

Implantable medical devices, such as cardiac pacemakers or defibrillators, typically include a metal housing having a feedthrough device (often referred to simply as a feedthrough) which establishes electrical connections between a hermetically sealed interior of the metal housing and an exterior of the medical device. Feedthroughs typically include an insulator and a frame-like metal ferrule disposed about a perimeter edge of the insulator. The ferrule is configured to fit into a corresponding opening in the metal housing, with the ferrule typically being welded to the housing to ensure a hermetic seal with respect to the interior of the housing. Electrical conductors or "feedthrough pins" extend through the insulator to provide electrical pathways between the hermetically sealed interior of the housing and an exterior of the medical device. The insulator electrically isolates the feedthrough pins from one another and from the metal ferrule and housing.

The ferrule and insulator are typically joined to one another via a brazing or soldering process. Forming the metal ferrule (typically via a machining process) to meet the tight tolerances required to maintain a desired gap (about 10-50 μm) between the ferrule and insulator that is necessary to achieve a quality braze joint is difficult. Additionally, if the gap is not maintained during the brazing process or if the brazing itself is not properly performed, a weak joint may be formed between the ferrule and the insulator that may lead to premature failure of the implantable device.

For these and other reasons there is a need for the embodiments of the present disclosure.

Brief Description of the Drawings

The accompanying drawings are included to provide a further understanding of embodiments and are incorporated in and constitute a part of this specification. The drawings illustrate embodiments and together with the description serve to explain principles of embodiments. Other embodiments and many of the intended advantages of embodiments will be readily appreciated as they become better understood by reference to the following detailed description. The elements of the drawings are not necessarily to scale relative to each other. Like reference numerals designate corresponding similar parts.

Figures 1A and 1B illustrate a feedthrough device in accordance with the prior art.

Figure 2A illustrates a cross-sectional view of a feedthrough assembly in an implantable medical device in accordance with one embodiment.

Figure 2B illustrates a cross-sectional view of a feedthrough assembly in an implantable medical device in accordance with one embodiment.

Figures 3 illustrates a cross-sectional view of a feedthrough assembly in an implantable medical device in accordance with one embodiment.

Figure 4 illustrates a method of forming a feedthrough device in accordance with one embodiment.

Figure 5 illustrates a method of segmenting a length of a bulk feedthrough device into a plurality of individual feedthroughs in accordance with one embodiment.

Figure 6 illustrates a method of forming a feedthrough device in accordance with one embodiment.

Figure 7 is a flow diagram illustrating a method of forming a feedthrough assembly in accordance with one embodiment.

Detailed Description

In the following Detailed Description, reference is made to the accompanying drawings, which form a part hereof, and in which is shown by way of illustration specific embodiments in which the invention may be practiced. In this regard, directional terminology, such as "top," "bottom," "front," "back," "leading," "trailing," etc., is used with reference to the

orientation of the Figure(s) being described. Because components of embodiments can be positioned in a number of different orientations, the directional terminology is used for purposes of illustration and is in no way limiting. It is to be understood that other embodiments may be utilized and structural or logical changes may be made without departing from the scope of the present invention. The following detailed description, therefore, is not to be taken in a limiting sense, and the scope of the present invention is defined by the appended claims.

It is to be understood that the features of the various exemplary embodiments described herein may be combined with each other, unless specifically noted otherwise.

In accordance with one embodiment of the present disclosure, a method of forming a feedthrough device for an implantable medical device is provided. A bulk insulator having a longitudinal length extending between first and second end faces is provided, the bulk insulator including one or more conducting elements extending therethrough between the first and second end faces, and having a perimeter surface along the longitudinal length. A metal, metal alloy, or cermet is deposited on the perimeter surface to form a ferrule directly on the perimeter surface of the bulk insulator. After the metal, metal alloy, or cermet has been deposited, the bulk insulator is segmented along the longitudinal length into individual segments each having a thickness, with each individual segment forming a feedthrough device.

According to one embodiment, the perimeter surface of the bulk insulator is metallized with a metallization layer prior to depositing the metal, metal alloy, or cermet. In one embodiment, the metallization layer is of a metal selected from a group consisting of titanium, niobium, platinum, palladium, and gold, and has a thickness in a range from 0.2 μm to 10 μm.

Embodiments described herein for depositing a metal, metal alloy, or cermet on the insulator to form a ferrule directly on the perimeter surface thereof provides advantages over known processes. Depositing the metal ferrule directly on the insulator, or on a metallized layer thereon, eliminates braze and solder joints which exist between the ferrule and insulator of conventional ferrules,

thereby providing a stronger and more reliable hermetic seal there between. Depositing the ferrule directly on the insulator also eliminates the costly and time consuming process of first machining ferrules to the tight tolerances required to provide a proper gap between the insulator and ferrule necessary to produce quality brazing and solder joints. It also eliminates the necessity of maintaining such gap as required to ensure quality joints during the brazing and soldering process itself, thereby resulting in stronger and more consistent hermetic seals between the ferrule and insulator.

According to one embodiment, the metal, metal alloy, or cermet is deposited using a suitable powder deposition process. In one embodiment, the powder deposition process comprises a Laser Engineered Net Shaping™ process to coat the perimeter surface of the insulator with the metal, metal alloy, or cermet. In one embodiment, the powder deposition process comprises a plasma thermal spraying process to coat the perimeter surface of the insulator. In one embodiment, the metal or metal alloy is deposited with a thickness in a range from 200 μm to 800 μm. In one embodiment, the metal or metal alloy forming the ferrule comprises one of a group consisting of niobium, titanium, titanium alloy, tantalum, tungsten, molybdenum, cobalt, zirconium, chromium, platinum, and alloy combinations thereof. In one embodiment, the cermet comprises a combination of a ceramic, such as aluminum oxide (Al_2O_3) and Zirconium dioxide (ZrO_2), for example, and a metal, such as Niobium, Molybdenum, titanium, cobalt, zirconium, chromium, platinum, tantalum, and iridium, for example.

In one embodiment, machining is performed after deposition of the metal, metal alloy, or cermet on the perimeter surface of the insulator to provide the ferrule with a desired final cross-sectional shape. In one embodiment, deposition of the metal, metal alloy, or cermet is finely controlled so that the resulting ferrule has a desired final cross-sectional shape. Controlling deposition of the metal, metal alloy, or cermet in this fashion substantially reduces or eliminates the time and expense required to machine conventional ferrules.

According to one embodiment, the insulator comprises aluminum oxide and the conductive elements comprise a cermet. Using cermet conductive

elements also eliminates braze and/or solder joints between the conductive elements and the insulator and such that the entire ferrule is brazless/solderless.

In one embodiment, the insulator is preheated using a laser to a desired temperature within a range from 800 to 1500 °C prior to depositing the metal, metal alloy, or cermet on the perimeter surface. According to one embodiment, the insulator is preheated to the desired temperature in a time period ranging from 15 to 180 seconds. In one embodiment, the laser is used to ramp down a temperature of the insulator after deposition of the metal, metal alloy, or cermet thereon. Controlling the temperature of the insulator in this fashion reduces or eliminates the potential for cracking of the insulator that might otherwise result from a thermal shock during the deposition process.

Another aspect provides a method of forming a feedthrough device for an implantable medical device including providing an insulator having one or more conducting elements extending therethrough, the insulator having a perimeter edge surface, metallizing the perimeter edge surface to provide a metallized layer thereon, and depositing a metal, metal alloy, or cermet having a thickness in a range from 200 to 800 μm on the metallized layer to form a ferrule thereon and thereby form the feedthrough device. According to one embodiment, such method provides depositing the metal, metal alloy, or cermet on individual feedthrough devices in lieu of forming such devices from a bulk insulator.

Such method provides several of the advantages discussed above, including forming stronger and more consistent and uniform hermetic seals between ferrules and insulators relative to conventional solder and braze joints, and the elimination of the formation and maintenance of a high-tolerance gap between the ferrule and insulator which is required for producing convention solder and braze joints.

One embodiment provides a feedthrough for an implantable medical device including a ferrule comprising a metal, metal alloy, or cermet that is configured to be jointed to a case of the implantable device, an insulator substantially surrounded by the ferrule and sharing an interface therewith, the insulator comprising a glass or ceramic material, and conductive elements formed through the insulator providing an electrically conductive path through

the insulator. The feedthrough is characterized in that there is no braze, solder, or weld joint at the interface between the ferrule and the insulator and that there is no braze or solder at interfaces between the insulator and the conductive elements. The complete absence of braze or solder joints which characterizes such a feedthrough enables the feedthrough to provide an improved and more durable hermetic seal for an implantable medical device in which it is employed.

Figures 1A and 1B respectively illustrate perspective and sectional views of a conventional feedthrough device 10, such as for an implantable medical device. Feedthrough device 10 includes a ferrule 12, an insulator 14 and feedthrough pins 16. Ferrule 12 is an annular, frame-like metal structure forming an interior opening in which insulator 14 is disposed. Feedthrough pins 16 extend through insulator 14, with insulator 14 serving to electrically insulate feedthrough pins 16 from one another and from ferrule 12.

Ferrule 12 is configured to fit into a corresponding opening of a metal case for an implantable medical device. Typically, ferrule 12 is welded to the metal case so that it is tightly secured thereto and to ensure a hermetic seal with respect to an interior space of the medical device defined by the metal case. Feedthrough pins 16 extending through insulator 14 provide electrical connection from the interior to the exterior of the metal case while maintaining a hermetic seal. Flanges 15 are sometimes provided on ferrule 12 to further aid in securing feedthrough device 10 to the opening of the case of the implantable medical device and ensuring it`s hermetic seal.

Typically, ferrule 12 is a bio-compatible metal, such as titanium or niobium, while insulator 14 is a ceramic or glass material. When coupling insulator 14 to ferrule 12, a perimeter edge of insulator 14 is typically metalized (i.e. a metal coating is applied, such as by sputtering, for example) to provide a thin metal coating 20 thereon, and insulator 14 is placed within the interior opening defined by ferrule 12. A brazing process, using a brazing material 22, such as gold, is then carried to join ferrule 12 to insulator 14 via metal coating 20. Similarly, a braze 18 is often used to couple feedthrough pins 16 to insulator 14.

In order to achieve a quality braze between ferrule 12 and insulator 14, a proper gap needs to be maintained between ferrule 12 and insulator 14, typically about 10-50 μm, so that capillary action will properly draw brazing material 22 into the gap to create a strong and reliable hermetic seal. Forming ferrule 12, typically via machining processes, to meet the tight tolerances required to provide the desired gap between the ferrule 12 and insulator 14, as well as to the dimensions of the opening in the metal case, can be difficult. If the gap between the ferrule 12 and insulator 14 is too small, the brazing material 22 may not be adequately drawn into the gap, resulting in a weak joint. Also, during the brazing process, intermetallics are always formed between the brazing material 22 and ferrule 12, with the intermetallics being brittle as compared to the brazing material 22. If the gap is too small, the amount of intermetallics may be large relative to the amount of brazing material 22, resulting in a brittle joint that can crack and compromise the hermetic seal.

Figure 2A is cross-sectional view illustrating a feedthrough device 110 according to one embodiment of the present disclosure. Feedthrough device 110 includes a ferrule 112, an insulator 114, and conducting elements 116, with insulator 114 having a perimeter edge surface or perimeter surface 115 extending between a first or upper major surface 117a and a second or lower major surface 117b. According to embodiments described herein, ferrule 112 is formed from one of a metal, metal alloy, or cermet. Feedthrough device 110 is characterized, relative to conventional feedthrough devices, by the absence of a metallization layer and a braze material (such as metallization layer 20 and braze material 22 of Figure 1B, for example) between the material of ferrule 112 and the glass or ceramic material of insulator 114. Instead, according to embodiments of the present disclosure, the metal of ferrule 112 is deposited directly on the material of insulator 114 on perimeter 115, using deposition techniques which will be discussed in greater detail below, to form a hermetic seal therebetween without the use of braze or solder.

Ferrule 112 can be formed using the deposition techniques to have a variety of shapes and cross-sections. According to one embodiment, as illustrated by Figure 2, ferrule 112 is formed with a flange 130 extending

laterally along an upper surface 132, resulting in a notch 134 along a lower surface 136, giving ferrule 112 a stepped, rectangular shape in cross-section. According to one embodiment, a desired final shape of ferrule 112 is achieved directly via the deposition process. In one embodiment, machining is performed after initial deposition of the metal of ferrule 112 to achieve the desired final shape of ferrule 112.

According to one embodiment, as illustrated by Figure 2A, insulator 114 and conducting elements 116 are formed in a first process such that interfaces between insulator 114 and conducting elements 116 are also hermetically sealed without the use of a braze or solder. According to one example of such an embodiment, insulator 114 is a ceramic material, such as aluminum oxide (Al_2O_3), and conducting elements 116 are a cermet material.

In the context of one embodiment, the terms, "cermet" or "cermet-containing," refers composite materials made of ceramic materials in a metallic matrix (binding agent). These are characterized by their particularly high hardness and wear resistance. The "cermets" and/or "cermet-containing" substances are cutting materials that are related to hard metals, but contain no tungsten carbide hard metal and are produced by powder metallurgical means. A sintering process for cermets and/or cermet-containing elements is the same as that for homogeneous powders, except that the metal is compacted more strongly at the same pressuring force as compared to the ceramic material. The cermet-containing bearing element has a higher thermal shock and oxidation resistance than sintered hard metals. According to one embodiment, the ceramic components of the cermet are aluminum oxide (Al_2O_3) and zirconium dioxide (ZrO_2), for example, and niobium, molybdenum, titanium, cobalt, zirconium, chromium, and platinum , for example, may be employed as the metallic components.

According to one embodiment, the ceramic of insulator 114 of Figure 2A is a multi-layer ceramic sheet into which a plurality of vias is introduced. The cermet of conducting elements 116 is then introduced into the vias. In one embodiment, both materials are introduced in a green state, and the combination is fired together. Accordingly, the joining of the insulator 114 and conducting

elements 116 forms a hermetic seal therebetween without the use of braze or solder.

Figure 2B is a cross-sectional view of feedthrough device 110 of Figure 2A, but further includes a metallized layer 138 disposed on the perimeter surface 115 of ceramic insulator 114 at the interface between insulator 114 and the material of ferrule 112. According to one embodiment, metallized layer 138 is disposed on insulator 114 via a sputter coating process. According to one embodiment, metallized layer 138 is disposed on insulator 114 via an electroplating process. According to one embodiment, metallized layer 138 comprises a bio-compatible metal, such as Niobium, Platinum, Palladium, Titanium, and Gold, for example. In one embodiment, metallized layer 138 is deposited so as to have a thickness in a range from 0.2 to 10 μm. As will be described in greater detail below, after deposition of metallized layer 138 on insulator 114, a metal, metal alloy, or cermet is deposited on and built-up on metallized layer 138 to form ferrule 112.

Figure 3 is a cross-sectional view illustrating portions of an implantable medical device 140 having a metal case 142 in which feedthrough device 110 of Figure 2A is installed. In one embodiment, feedthrough device 110 is positioned within an opening in metal case 142, and ferrule 112 is laser welded to metal case 142 such that an interior 144 of metal case 142 is hermetically sealed relative to its exterior 146.

By forming insulator 114 and conducting elements 116 using a cermet material, as described above, and by depositing the metal of ferrule 112 directly on a perimeter surface of insulator 114, a ferrule formed according to embodiments of the present application, such as ferrule 112 of Figure 2A, provides hermetic seals between ferrule 112 and insulator 114, and between insulator 114 and conducting elements 116 without the use of braze or solder. As such, a feedthrough device according to the present disclosure, such as feedthrough device 110 of Figure 2A, eliminates shortcomings associated with the braze and/or solder joints of conventional feedthrough devices (such as illustrated by Figures 1A and 1B, for example), and provides a more reliable

hermetic seal between an interior and exterior of an implantable device, such as between the interior 144 and exterior 146 of implantable medical device 140.

According to embodiments, a suitable deposition process, including suitable powder deposition processes, is employed to deposit the material forming ferrule 112 (e.g. metal, metal alloy, cermet) directly on insulator 114. Examples of such deposition processes include powder deposition processes such as Laser Engineered Net Shaping™ and plasma thermal spraying, for example.

Figure 4 is a block and schematic diagram generally illustrating one embodiment of a Laser Engineered Net Shaping™ (LENS®) process for depositing a metal , metal alloy, or cermet on insulator 114 to form ferrule 112. The LENS process employs a high power laser 150, a powder delivery system 152, a deposition or print head 154, and a translation table 156.

According to one embodiment, a bulk insulator 114a having a length "L" between first and second end surfaces 115a, 115b, and one or more conducive elements extending through insulator 114a from first end surface 115a to a second end surface 115b, such as conductive elements 116a and 116b, is mounted on translation table 156. According to one embodiment, bulk insulator 114a has been previously formed, such as by the cermet process described above, so that conductive elements 116a and 116b comprise cermet and a brazeless/solderless hermetic seal exists between conductive elements 116a and 116b. According to one embodiment, bulk insulator 114 includes a metallization layer 138a disposed on its external circumferential surface, such as via a sputtering process or electroplating process as described above. Although illustrated in Figure 4 as having a circular cross-section, bulk insulator 114a can have a variety of cross-sectional shapes, such as rectangular or oval, for example.

During the deposition process, laser 150 provides a high power laser beam 160 which travels through the center of deposition head 154 and is focused to a point on the surface of bulk insulator 114a by one or more lenses 162. Powder delivery system 152 provides a fine powder 164 of a metal, metal alloy, or cermet components to a plenum 166 about the circumference of deposition

head 154. The fine powder 164 is coaxially injected into the focused high power laser beam 160a at an outlet 168 of deposition head 154. Powder 164 can be circumferentially injected into focused laser beam 160a by gravity or by using a pressurized carrier gas. The powder 164 is sintered by focused laser beam 160a and deposited on the surface of bulk insulator 114a, or onto metallized layer 138a when present, such as illustrated by the exemplary embodiments of Figures 2A and 2B.

According to one embodiment, powdered metals used to form ferrule 112 include Ti (Titanium), Ti6Al4V (Titanium Alloy), Nb (Niobium), Ta (Tantalum), W (Tungsten), or alloy combinations of these, for example. According to one embodiment, cermet powder includes a ceramic component, such as Aluminum Oxide (Al_2O_3) and Zirconium dioxide (ZrO_2), for example, and a metal component such as Niobium, Molybdenum, titanium, cobalt, zirconium, chromium, platinum, tantalum, and iridium, for example. According to one embodiment, combinations of these components forms the cermet powder which is laser sintered onto insulator 114a.

According to one embodiment, lasers used for laser 150 include Nd:YAG, Fiber, and CO_2, for example. According to one embodiment, Nd:YAG and Fiber are employed due to their approximately 1 μm wavelength having a higher optical absorption into the metals.

As the melted/sintered powder 164 is deposited onto the surface of bulk insulator 114 (or onto metallization layer 138a if present), translation table 156 is controlled so as to rotate bulk insulator 114a about the x-axis and to translate bulk insulator 114a along the x-axis to deposit melted/sintered powder 164 in a desired fashion on the circumferential surface of bulk insulator 114a and thereby form ferrule 112. Melted/sintered powder 164 is deposited in a series of layers to build the deposited metal up to a desired thickness to form ferrule 112. According to one embodiment, translation table 156 also controls movement of bulk insulator 114a along the z-axis as the thickness of the material deposited on bulk insulator 114a increases. In other embodiments, a position of deposition head 154 along the z-axis can be controlled.

According to one embodiment, deposition of the metal, metal alloy, or cermet onto bulk insulator 114a is precisely controlled so that the metal, metal alloy, or cermet is built-up and directly deposited with the desired final shape of ferrule 112, such as the rectangular, stepped shape of ferrule 112 of Figure 2A, without a need for post-deposition machining. According to one embodiment, the metal, metal alloy, or cermet is deposited on bulk insulator 114 in a range from 200 μm to 800 μm to form ferrule 112. In one embodiment, an inert gas 170 is supplied to deposition head 154 to shield the metal or metal alloy from oxygen, thereby suppressing oxidation of the metal or metal alloy, and so that the metal or metal alloy sinters properly and can be controlled more accurately. According to one embodiment, mechanical machining is performed after the initial deposition of the metal, metal alloy, or cermet on bulk insulator 114a to achieve the desired final shape of ferrule 112.

In one embodiment, an additional laser180 is used to preheat the material of bulk insulator 114a to reduce the thermal shock from laser 150 during the deposition process and thereby reduce the chance of cracking of the ceramic material of bulk insulator 114a during deposition. According to one embodiment, laser 180 is configured to scan the surface of insulator 114 to raise the temperature of bulk insulator 114a from room temperature to a temperature of 800-1,500 °C. In one embodiment, laser 180 is a CO_2 laser. According to one embodiment, laser 180 using a ramp rate of 15-180 seconds to heat bulk insulator 114a from room temperature to the desired preheat temperature. According to one embodiment, laser 180 is similarly used to carry out a cool down process to ramp the temperature down to room temperature after deposition of the metal of ferrule 112.

In one embodiment, the preheating of bulk insulator 114a, the deposition of the metal, metal alloy, or cermet onto the surface of bulk insulator 114a to form ferrule 112, and the subsequent cool down process is carried out in a vacuum or in an inert environment (e.g. argon) to keep the metal or metal alloy from being oxidized.

As illustrated by Figure 5, according to one embodiment, after completing the deposition of the material forming ferrule 112 on the length "L"

of bulk insulator 114a to form a resulting length "L" of a bulk feedthrough device 110a, the bulk feedthrough device 110a is cut into segments to form multiple individual feedthrough devices 110 (such as illustrated by Figures 2A and 2B), each having a desired thickness "Th". According to one embodiment, the length "L" of bulk feedthrough device 110a is segmented using a saw 182.

In other embodiments, not illustrated herein, in lieu of performing the deposition of the material of ferrule 112 on bulk insulators (such as bulk insulator 114a), individual insulators 114 having one or more conducting elements 116 extending therethrough are coated with the metal, metal alloy, or cermet, such as by the above described process of Figure 4, to form individual feedthrough devices 110.

Figure 6 is a block and schematic diagram generally illustrating one embodiment of a process for depositing material directly on bulk insulator 114a (or on individual insulators 114) to form ferrule 112. The process illustrated by Figure 5 is commonly referred to as plasma thermal spraying, and employs a chamber 190 in which a plasma gun 192 is disposed. Plasma gun 192 includes a body 194 having a conical cavity 196 in which a cathode 198 is disposed and forms an annular cavity 200 there about. A low-pressure, inert gas atmosphere is created within an interior of chamber 190 (e.g. argon, an argon-helium mixture, or an argon-hydrogen mixtures, for example).

During a coating process, a power supply 204 is energized to create an arc 206 between 194 and cathode 198 in annular passage 200. A plasma gas, such as a mixture of argon and helium, for example, is flowed through annular passage 200 and a high temperature, high velocity plasma gas stream 210 is expelled via nozzle 212. A powder injection system 214 injects a fine powder 216 of a metal, metal alloy, or cermet components which is entrained in the plasma gas stream 210, and which are subsequently melted and deposited on the surface of bulk insulator 114a to form ferrule 112. Materials similar to those described above with respect to the LENS process of Figure 4 may be employed for the metal, metal alloys, and cermet. As also described above with regard to the LENS process of Figure 4, a translation table 218 rotates bulk insulator 114a about the x-axis and controls lateral movement of bulk insulator 114a along the

x-axis so as to deposit the materials forming ferrule 114 in a desired fashion on the outer diameter of the ceramic material of bulk insulator 114a.

Similar to that described above with respect to the LENS process of Figure 4, according to one embodiment, deposition of the metal, metal alloy, or cermet onto bulk insulator 114a (or onto metallized layer 138 when present) is precisely controlled so that the material is built-up and directly deposited with the desired final shape of ferrule 112, such as the rectangular, stepped shape of ferrule 112 of Figure 2A, without the need for post-deposition machining. According to one embodiment, the metal, metal alloy, or cermet is deposited on bulk insulator 114a in a range from 200 μm to 800 μm to form ferrule 112. In other embodiments, post-deposition machining is performed to achieve a desired final shape of ferrule 112.

According to one embodiment, a laser 220 is employed to carry out preheating and cool down processes similar to LENS process described above by Figure 4. Also, as described above by Figure 5, after deposition of ferrule 112 onto bulk insulator 114a by the plasma thermal spraying process of Figure 6, the resulting bulk feedthrough device 110a is segmented to individual feedthrough devices 110, such as illustrated by Figures 2A and 2B, for example.

Figure 7 is a flow diagram illustrating a process 250 of forming a feedthrough device in accordance with one embodiment. Process 250 begins at 252 with receiving an insulator having one or more conducting elements extending therethrough. According to one embodiment, the insulator is one such as insulator 114 of Figure 2A, wherein conducting elements 116 are of a cermet material such that there is no braze or solder at interfaces between conductive elements 116 and the material of insulator 114, such as a glass or ceramic material. According to one embodiment, the insulator is a bulk insulator, such as bulk insulator 114a illustrated by Figure 4, which has a length "L" between opposing end faces, with cermet conducting elements extending between the opposing faces. According to one embodiment, the insulator has a circular or oval cross-section, for example, but can have any number of cross-sectional shapes.

According to one embodiment, after receiving the insulator, the insulator is optionally metallized to form a metallization layer about an exterior edge surface of the insulator, such as metallization layer 138 about a perimeter edge surface 115 of insulator 114 as illustrated by the embodiment of Figure 2A.

At 258, a material, such as a metal, metal alloy, or cermet, for example, for forming a ferrule, such as ferrule 112 of the embodiment of feedthrough 110 illustrated by Figure 2A, is deposited on a perimeter surface of the insulator. According to one embodiment, the material forming ferrule 112 is deposited using a LENS® process, such as generally illustrated and described by Figure 4. According to one embodiment, the material forming ferrule 112 is deposited using a plasma thermal spraying process, such as generally illustrated and described by Figure 6. According to one embodiment, the process for deposition of the material forming the ferrule is controlled to the extent that the material is deposited such that the ferrule is directly formed with a desired final shape (e.g. cross-sectional shape). In one embodiment, the material is deposited on individual insulators, such insulator 114 of Figure 2A. In one embodiment, the material is deposited on the perimeter surface of a bulk insulator, such as bulk insulator 114a of Figure 4, for example.

Optionally, at 256, according to one embodiment, the perimeter surface of the insulator is preheated with a laser, for example, to a desired temperature prior to the deposition of metal at 258. Preheating the perimeter surface of the insulator, such as with laser 180 of Figure 4, reduces the thermal shock to insulator 114 that might otherwise be caused by the material deposition process, and thereby reduces cracking of insulator 114 during the deposition process.

According to one embodiment, process 250 ends at 258. However, in one embodiment, process 250 optionally includes, as indicated at 260, performing a controlled cool down of insulator 114 and the deposited (e.g. metal, metal alloy, cermet), such as via laser 180 of Figure 4. Such a controlled cool down further reduces the chances for thermally induced cracking of the material of insulator 114 and improves the chances of achieving a better bond between the deposited material forming ferrule 112 and the ceramic or glass material, for example, of insulator 114.

Additionally, according to one embodiment, process 250 optionally includes, at 262 a machining process when the material of ferrule 112 is not deposited so as to have a desired final shape. Such machining process machines the "rough" deposition of the material ferrule 112, such as deposited by the processes of Figures 4 and 6, for example, to a final desired shape.

Although specific embodiments have been illustrated and described herein, it will be appreciated by those of ordinary skill in the art that a variety of alternate and/or equivalent implementations may be substituted for the specific embodiments shown and described without departing from the scope of the present invention. This application is intended to cover any adaptations or variations of the specific embodiments discussed herein. Therefore, it is intended that this invention be limited only by the claims and the equivalents thereof.

WHAT IS CLAIMED IS:

1. A method of forming a feedthrough device for an implantable medical device, the method comprising:

providing a bulk insulator having a longitudinal length extending between first and second end faces, and including one or more conducting elements extending therethrough between the first and second end faces, the bulk insulator having a perimeter surface along the longitudinal length; and

depositing one of a metal, metal alloy, or cermet on the perimeter surface to form a ferrule directly thereon, wherein the ferrule can be joined to other components of the implantable medical device.

2. The method of claim 1, wherein the depositing of the metal, metal alloy, or cermet comprises a powder deposition process.

3. The method of claim 2, wherein the powder deposition process comprises a Laser Engineered Net Shaping™ process to coat the perimeter surface of the insulator with the metal, metal alloy, or cermet.

4. The method of claim 2, wherein the powder deposition process comprises a plasma thermal spraying process to coat the perimeter surface of the insulator with the metal, metal alloy, or cermet.

5. The method of claim 1, further including metallizing the perimeter surface to provide a metallized layer on the perimeter surface prior to depositing the metal, metal alloy, or cerment.

6. The method of claim 5, wherein the metallized layer has a thickness in a range from 0.2 μm to 10 μm.

7. The method of claim 5, wherein the metallized layer is of a metal comprising one selected from a group consisting of titanium, niobium, platinum,. Palladium, and gold.

8. The method of claim 1, wherein after the metal, metal alloy, or cermet has been deposited, the method further includes segmenting the bulk insulator along the longitudinal length into individual segments each having a thickness, each individual segment forming a feedthrough device.

9. The method of claim 1, further including preheating the insulator with a laser to a desired temperature within a range from 800 to 1500 °C prior to depositing the metal or metal alloy on the perimeter surface.

10. The method of claim 1, wherein the preheating from room temperature to the desired temperature has a ramp rate from 15 to 180 seconds.

11. The method of claim 1, further including using a laser to ramp down a temperature of the insulator from a temperature at a time of the depositing of the metal or metal alloy to room temperature.

12. The method of claim 1, wherein depositing the metal or metal alloy includes controlling deposition of the metal or metal alloy so that the resulting ferrule has a desired final cross-sectional shape.

13. The method of claim 1, further including machining the metal or metal alloy deposited on the perimeter surface of the insulator to provide the ferrule with a desired final cross-sectional shape.

14. The method of claim 1, wherein the metal or metal alloy forming the ferrule comprises one of a group consisting of niobium, titanium, titanium alloy, tantalum, tungsten, molybdenum, cobalt, zirconium, chromium, platinum, and alloy combinations thereof.

15. The method of claim 1, wherein the insulator comprises aluminum oxide and the conductive elements comprise a cermet.

16. The method of claim 1, wherein depositing the metal or metal alloy includes depositing the metal or metal alloy with a thickness in a range from 200 μm to 800 μm.

17. A method of forming a feedthrough device for an implantable medical device, the method comprising:

providing an insulator having one or more conducting elements extending therethrough, the insulator having a perimeter edge surface;

metallizing the perimeter edge surface to provide a metallized layer thereon; and

depositing one of a metal, metal alloy, or cermet having a thickness in a range from 200 to 800 μm on the metallized layer using a powder deposition process to form a ferrule thereon and thereby form the feedthrough device.

18. The method of claim 17, wherein the metallized layer has a thickness in a range from 0.2 μm to 10 μm and comprises a metal selected from a group of metals consisting of titanium, niobium, platinum,. Palladium, and gold.

19. The method of claim 17, wherein the powder deposition process comprises a Laser Engineered Net Shaping™ process.

20. The method of claim 17, wherein the powder deposition process comprises a plasma thermal spraying process.

21. A feedthrough for a medical implantable device comprising:

a ferrule comprising a metal that is configured to be welded to a case of the implantable device;

an insulator substantially surrounded by the ferrule and sharing an interface therewith, the insulator comprising a glass or ceramic material;

conductive elements formed through the insulator providing an electrically conductive path through the insulator;

characterized in that there is no braze, solder, or weld joint at the interface between the ferrule and the insulator and that there is no braze or solder at interfaces between the insulator and the conductive elements.