CONTACTING ARRANGEMENT COMPRISING A FEEDTHROUGH AND A FILTER STRUCTURE AND METHOD OF MAKING

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ABSTRACT

One aspect relates to a contacting arrangement for use in a housing of a medically implantable apparatus. Said contacting arrangement includes an electrical feedthrough device that includes at least one electrically insulating main feedthrough member and at least one electrical conducting element. The conducting element is designed to establish at least one electrically conducting connection between an interior of the housing and an exterior through the main feedthrough member. The conducting element is hermetically sealed with respect to the main feedthrough member. The at least one conducting element comprises at least one cermet. The contacting arrangement further includes an electrical filter structure which is arranged on a face of the feedthrough device. Furthermore, said filter structure is connected to the conducting element by means of at least one electrical surface connection.
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BACKGROUND

[0001] One aspect concerns an electrical contacting arrangement comprising a feedthrough and a filter structure for fitting in a housing of a medically implantable device. One aspect also concerns a method for producing an electrical contacting arrangement for a medically implantable device.

[0002] An electrical arrangement for a medically implantable device with the features of the preamble of claim 1 is disclosed in the document DE 10 2009 033 972.


[0004] In DE 697 297 19 T2, a description is given of an electrical feedthrough for an active implantable medical device—also referred to as an implantable device or a therapeutic system. Such electrical feedthroughs serve the purpose of establishing an electrical connection between a hermetically sealed interior and an exterior of the therapeutic system. Known implantable therapeutic systems are pacemakers or defibrillators, which usually have a hermetically sealed metal housing that is provided on one side with a connector, also known as a header or lead part. This connector has a cavity with at least one connection socket, which serves for the contacting of electrode leads. The connection socket at the same time has electrical contacts to connect the electrode leads electrically to the electronic control system inside the housing of the implantable therapeutic system. An essential precondition for such an electrical feedthrough is the hermetic sealing with respect to a surrounding space. Consequently, lead wires that are introduced into an electrically insulating main body and are also referred to as leadthrough elements, by way of which the electrical signals run, must be introduced into the main body without any gaps. It has been found to be a disadvantage in this respect that the lead wires are generally made of a metal and are introduced into a ceramic main body. In order to ensure a permanent connection between the two elements, the inner surface of a through-opening—also referred to as openings—in the main body is metalized in order to solder in the lead wires. This metallization and soldering in the through-opening has been found to be difficult to apply. A uniform metallization of the inner surface of the bone, and consequently a hermetically sealed connection of the lead wires to the main body, by soldering can only be ensured by means of cost-intensive methods. The soldering process itself requires further components, such as for example solder rings. Moreover, the process of connecting the lead wires to the previously metalized insulators using the solder rings is a process that is complex and difficult to automate.

[0005] In the document U.S. Pat. No. 7,564,674 B2 a description is given of a feedthrough for implantable devices in which connection pins of metal extend through openings in an insulator. The inner sides of the openings are metalized, in order to connect the connection pins to the inner sides of the openings by means of solder. The feedthrough also includes a filter capacitor, which in the same way has openings with metalized inner sides, the connection pins similarly extending through these openings and being connected to them by solder. The connection of the filter capacitor to the connection pins requires a further soldering step during production, on the cylindrical inner side of the openings. There are consequently multiple connections, to be established by soldering, concerning a large number of components. On the one hand, this makes the production process highly complex and on the other hand it gives rise to a high degree of susceptibility to errors in production, since the soldering steps concern various components, which can each only be soldered in a certain way. For example, on account of the proximity of the various components to be soldered to one another, there is the risk of undesired soldered connections occurring, especially because in every soldering step already applied soldered connections are partially melted. Furthermore, the openings in the filter capacitor have to be brought into line exactly with the connection pins when it is fitted on. For example, in the case of small dimensions and a large number of connection pins, this requires particular precision when joining the parts together and also requires exact matching of the geometries of the connection pins and the openings, since otherwise gaps and/or mechanical stresses occur. To sum up, the use of extending-through wires as connection pins and the fitting on of the filter capacitor impose particularly high demands on the accuracy of the production process, since otherwise insecure electrical contacts and/or mechanical stresses occur at the feedthrough.

[0006] The object generally is to overcome at least partially the disadvantages that arise from the prior art.

BRIEF DESCRIPTION OF THE DRAWINGS

[0007] 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.

[0008] FIG. 1 illustrates an overview of a medically implantable device with a contacting arrangement according to one embodiment;

[0009] FIG. 2 illustrates an overview of a contacting arrangement according to one embodiment, comprising a feedthrough and a filter structure;

[0010] FIG. 3 illustrates a representation of a filter structure of the contacting arrangement according to one embodiment;

[0011] FIG. 4 illustrates a representation of the contacting arrangement according to one embodiment, comprising a feedthrough and a filter structure; and

[0012] FIG. 5 illustrates an embodiment of the contacting arrangement according to one embodiment, comprising a feedthrough and a filter structure with several possible components.

DETAILED DESCRIPTION OF THE DRAWINGS

[0013] 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.

[0014] 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.

[0015] One aspect of the present connection provides a contacting arrangement for a medically implantable device with which at least one of the aforementioned disadvantages is at least partially avoided.

[0016] Another aspect provides a contacting arrangement comprising a feedthrough and a filter structure that can be produced in a simple way, with high precision and with low reject rates.

[0017] The subject matter of the generic claims makes a contribution to achieving at least one of the objects. The subclaims that are dependent on these claims present refinements of the subject.

[0018] In some embodiments, an electrical contacting arrangement for fitting in a housing of a medically implantable device with the features of the claims is proposed. Also, a method for producing a contacting arrangement for a medically implantable device with the features of the claims is proposed. In the dependent claims, developments are respectively recited. Features and details that concern the contacting arrangement or the medically implantable device can also be applied to corresponding features and details of the method, and vice versa.

[0019] The contacting arrangement according to one embodiment allows particularly simple production of a contacting arrangement that is equipped with a filter. The electrical feedthrough and the filter structure may be produced and designed separately from one another; it is possible, for example only to provide the filter structure with a material of high permittivity and to provide the feedthrough with a non-conducting material that is less expensive or easier to handle. The two components, that is, the feedthrough and the filter structure, may be joined together in various ways, for example, by techniques that are already established and are consequently inexpensive and precise. For example, automatic machines that are already available off-the-shelf may be used for joining them together. The SMD technique may be used, that is, the technique for producing circuits with surface-mountable devices. Both components may be produced as ceramic components, so that the same production steps and the same starting materials can be used. In the text that follows, aspects are described in more detail.

[0020] The contacting arrangement according to one embodiment is intended for fitting in a housing of a medically implantable device. The contacting arrangement includes an electrical feedthrough. The feedthrough has at least one electrically insulating main feedthrough body. Furthermore, the feedthrough has at least one electrically conducting conducting element. The conducting element is designed to establish at least one electrically conducting connection between an interior of the housing and an exterior through the main body. The electrical connection provided in such a way is in one embodiment an ohmic connection—for example, a DC signal—with a low resistance, that is, a resistance of for example no more than 10 Ohms, 1 Ohm, 100 mOhms, 10 mOhms or 1 mOhm. The conducting element extends through the main body, that is, along the direction of longitudinal extent thereof. The conducting element may extend along a straight line. The conducting element in one embodiment extends along a longitudinal axis of the main body or parallel thereto. The conducting element may be configured as one or more parts and may have electrical intermediate elements, which provide a portion of the electrically conducting connection. The conducting element may have a connection surface that is in the interior and a connection surface that is directly adjacent to the exterior, which serve for the contacting of the conducting element. The interior is the term used, for example, to describe the entire space that lies inside the housing; further components of the contacting arrangement, for instance a filter structure, may extend within the interior. The conducting element or the connection surface that is adjacent to the interior may consequently be adjacent to a further component of the contacting arrangement according to one embodiment.

[0021] The conducting element is hermetically sealed with respect to the main feedthrough body. Consequently, the conducting element and the main body may have a common boundary surface. A seal that provides the hermetic sealing is formed at the boundary surface. The conducting element may, for example, be hermetically sealed with respect to the main feedthrough body by them being produced by a joint sintering process.

[0022] The seal is provided by a material-bonded contact of the conducting element with the main feedthrough body that is created by sintering.

[0023] The at least one conducting element includes at least one cermet. The cermet forms, for example, a structure that extends through in the longitudinal direction of the conducting element. This structure forms at least portions of the electrically conducting connection. The cermet has a high conductivity, which is in embodiments at least 1, at least 100, at least 10, at least 10^5 and in one embodiment at least 10^7 S/m.

[0024] The main feedthrough body is partially or completely formed from an electrically insulating material. This material corresponds to the at least one electrically insulating material described here of the main feedthrough body.

[0025] According to one embodiment, the contacting arrangement also includes an electrical filter structure. The filter structure is arranged on an end face of the feedthrough. The filter structure is in one embodiment arranged on the end face of the feedthrough that is facing the interior or adjacent thereto.

[0026] The filter structure is connected to the conducting element by way of an electrical surface connection. This makes it possible, for example, for the feedthrough and the filter structure to be produced individually. Furthermore, the feedthrough can be connected to the filter structure in a simple way, for example by the electrical surface connection being provided by an SMT (surface mounted technology) connection. There are numerous surface connection techniques known from the SMT area that can be used to connect the feedthrough to the filter structure. For example, the surface
connection may be provided by an electrically conducting adhesively bonded connection or by a soldered connection, for example, by using solder beads or solder paste that form or takes the surface connection in the molten state. Multiple surface connections are in one embodiment provided, providing the individual electrical connections between the feedthrough and the filter structure.

[0027] The filter structure may have a single frequency-selective component, for instance a capacitor or an inductor, or may have multiple frequency-selective components interconnected to one another. The filter structure and/or the feedthrough are, for example, physically independent. The filter structure may be connected to the feedthrough only by way of the at least one surface connection. Alternatively, the filter structure may be connected to the feedthrough only by way of the one surface connection in combination with an additional mechanical connection. Individually or physically independent is the term used to describe components (that is, the filter structure and/or the feedthrough) that form a coherent body of their own, apart from added connections such as the surface connection to other components. As a result, the filter structure and the feedthrough can be produced individually and connected to one another by a simple process, whereby the production process is simplified significantly. The surface connection may, for example, correspond in its properties and in the way in which it is established to a connection that is provided by an SMT connecting technique.

[0028] The electrical filter structure forms an electrical filter. The electrical filter structure is in connection with the electrically conducting connection that is established by the conducting element. An electrical filter structure is understood as meaning a network or a component that has different impedances at different frequencies of a signal applied to the filter structure. The electrical filter structure is designed for providing different attenuations for different frequency components of a signal that is transmitted by the electrically conducting connection. This dependence between frequency and attenuation is also referred to as frequency selectivity.

[0029] One embodiment provides that the conducting element has an end face, facing the filter structure, with a first surface contact. Furthermore, the filter structure has an end face, facing the feedthrough, with a second surface contact. The surface connection is provided between the first surface contact and the second surface contact. The feedthrough in one embodiment includes multiple conducting elements. Some of the conducting elements, or all of the conducting elements, have in each case (at least) a first surface contact. For some conducting elements, or for all of the conducting elements, the filter structure has (at least) a second surface contact. For some conducting elements, or for all of the conducting elements, of the feedthrough, an electrical surface connection between the filter structure and the feedthrough is provided. For example, each first surface contact is connected to an associated second surface contact by way of one of the electrical surface connections. The individual surface connections in one embodiment provide in each case an individual electrical connection between the filter structure and the feedthrough. The filter structure is in one embodiment connected to the feedthrough, such as an SMT component with multiple contacts is connected to a printed circuit board provided for it. The surface connections between the filter structure and the feedthrough correspond to connections created in such a way.

[0030] The surface contacts are planar in one embodiment. The first surface contacts in one embodiment come to lie on the respective associated second surface contacts. The first surface contacts terminate with the end face of the feedthrough, protrude from the end face or are recessed in the end face. The second surface contacts terminate with the end face of the feedthrough, protrude from the end face or are recessed in the end face, the first and second surface contacts being formed in this context as complementing one another. The first and/or second surface contacts in one embodiment are metalized or have a solderable coating.

[0031] A proportion of the conducting elements or all of the conducting elements run parallel to one another. A proportion of the conducting elements or all of the conducting elements of the feedthrough are arranged equidistantly from one another, in one embodiment in the form of a row or in the form of multiple, equidistant rows. In one embodiment this also applies to the surface connection, to the first surface contact and/or to the second surface contact. An electrical feedthrough according to one embodiment may include at least 2, 5, 10, 20, 50, 100, 200, 500 or 1000 conducting elements or first surface contacts. For example, the contacting arrangement according to one embodiment may include at least 2, 5, 10, 20, 50, 100, 200, 500 or 1000 feedthroughs or second surface contacts and/or contact points. The conducting elements, the first or second surface contacts, the surface connections and/or the feedthroughs are in one embodiment partially or completely formed individually, without direct electrical contact. The conducting elements in each case form an individual electrical connection, in one embodiment together with an associated surface connection.

[0032] The contacting arrangement may include one or more filter structures and/or one or more feedthroughs. A filter structure may be provided for two or more conducting elements of the electrical feedthrough.

[0033] The filter structure and/or peripheral portions of the end face of the feedthrough may be coated by an electrically insulating protective layer, on a side facing the interior. The protective layer forms a separating body with respect to an adjacent portion or with respect to adjacent portions of the interior. The protective layer is, for example, fluid-tight.

[0034] In a further embodiment, the surface connection provides a material-bonded connection. The material-bonded connection connects the filter structure to the conducting element. For example, the at least one first surface contact is connected to the at least one second surface contact by way of the material-bonded connection. In the case of multiple first and second surface contacts, each first surface contact is connected to at least one associated second surface contact by way of an individual material-bonded connection. The material-bonded connection is in one embodiment a soldered connection, a welded connection and/or an electrically conducting adhesively bonded connection or includes such a connection. The soldered connection may be provided by a molten solder bead or by molten solder paste; the welded connection may be provided by a pressure-welded connection or by an ultrasonic welded connection, and the electrically conducting adhesively bonded connection may be provided by a solidified conducting isotropic or anisotropic adhesive. For example, a soldered connection in which adhesive is additionally used for mechanical stabilization may be
established. As a result, an additional mechanical connection by the adhesive is obtained. Here, the adhesive may, for example, be non-conducting.

In a further embodiment, the filter structure includes at least one leadthrough. The leadthrough has a first end, which is connected—in one embodiment directly—to the conducting element of the feedthrough by way of the surface connection. This first end forms the aforementioned surface contact of the filter structure, which is also referred to as the second surface contact. The leadthrough of the filter structure and the conducting element of the feedthrough are connected in series, in one embodiment by way of the surface connection and, for example, by way of the first and the second surface contact and the surface connection that connects them.

The leadthrough, and the conducting element electrically connected thereto, connect the exterior of the housing with a contact point in the interior of the housing. The contact point is provided on the leadthrough of the filter structure. The contact point may be provided as a surface portion, for example, as a planar surface portion. The contact point is in one embodiment metalized and, for example, designed for the fastening of a bonding connection. The contact point may be configured as a bonding pad. Further electronic components, which are located in the interior, may be connected at the contact point. The contact point defines a surface with adjacent free space, and corresponds, for example, to an uncovered contact area. The contact point may be connected to a supply lead, for example, by way of a bonding connection, the contact point in one embodiment otherwise being covered by a portion of a protective layer, through which the supply lead passes. An individual contact point is provided in one embodiment for each leadthrough of the filter structure.

The contact point is located at a second end of the leadthrough, opposite from the first end of the leadthrough. For example, the contact point is located on the filter structure on a side of the filter structure that is opposite from the side adjacent to the leadthrough. The two sides are in one embodiment planar and parallel to one another.

The leadthrough of the filter structure includes a cermet, a metal or an electrically conducting alloy or consists substantially of such a material. The leadthrough in one embodiment runs through the filter structure. At least one further leadthrough may be provided on an outer side in the form of a conducting outer surface of the filter structure, which for example includes a metal layer. The metal layer may be formed on the outer side of the filter structure by metallization, for instance by vapor deposition, by immersion in a metal immersion bath, by sputtering, or by printing on a metal paste or by electrochemical or chemical deposition. The outer side of the filter structure runs circumferentially around the filter structure and between the two opposite sides of the filter structure, one of which is adjacent to the feedthrough. A leadthrough provided on the outer side runs along a line that connects the two sides.

A further aspect of one embodiment concerns the configuration of the filter structure. This may physically include independent components, for instance components such as SMD components with a connection of their own for connecting to a contact area of the filter structure. Furthermore, portions of the filter structure may themselves form components of the filter structure, the components being integrated in the filter structure, for example, without a connection of their own. In the latter case, electrically conducting and non-conducting materials that form the filter structure are suitably structured, in order for instance to form an electrode surface of a capacitor unit or a conducting portion of an inductor. The filter structure may include at least one physically independent component, at least one component integrated in the filter structure or both.

One embodiment therefore provides that the filter structure has at least one electrically conducting surface. The electrically conducting surface forms an electrode surface of a capacitor or forms the electrically conducting surface of a contact area. If the electrically conducting surface forms the electrode surface of the capacitor, the capacitor is a component integrated in the filter structure. If the electrically conducting surface forms a contact area, a physically independent component is connected thereto. Connected to the contact area is a frequency-selective component of the filter structure, which has, for example, a connection of its own. The frequency-selective component is a physically independent component. Furthermore, the filter structure may have at least one conducting portion, for example, a leadthrough of the filter structure. The conducting portion is provided here by an inductor of the filter structure or itself forms an inductor. Such an inductor is a component integrated in the filter structure.

Consequently, a capacitor that at least one electrode surface that is formed by a conducting material integrated in the filter structure may be regarded as a component integrated in the filter structure. Furthermore, an inductor or a conducting portion thereof that is formed by a conducting material integrated in the filter structure may be regarded as a component integrated in the filter structure. The conducting material is directly embedded in non-conducting material. The non-conducting material forms a main filter structure body. The non-conducting material may include at least one element of the group consisting of aluminium oxide, magnesium oxide, zirconium oxide, aluminum titanate and piezoelectric. In the case of a capacitor that is integrated in the filter structure, materials that can be used as a dielectric are used in one embodiment. The conducting material, for instance a cermet, a metal or an electrically conducting alloy, is embedded directly in the main filter structure body. In the case of the capacitor, the non-conducting material is in one embodiment a ferroelectric or paraelectric material, for example, barium titanate. Instead of a capacitor, an electromagnetic resonator may also be provided in the same way. The main filter structure body includes piezoelectric material, for example, on the electrically conducting surface.

A component with its own connections, by way of which it is connected to the remaining filter structure, may be regarded as a physically independent component. A physically independent component may be a discrete component or an integrated component with a carrier structure of its own, for instance a housing, a substrate or a frame. The physically independent component may include a housing of its own, to which the connections are fastened. The physically independent component includes connections of its own, by which it is connected to the remaining filter structure.

In the text that follows, a specific embodiment that has a capacitor as the integrated component in the filter structure is presented in more detail. The electrically conducting surface forms at least one electrode surface of the capacitor. The electrode surface forms at least one electrode, which is designed to generate an electric field, for example with respect to a further electrode or another conducting surface. The electric field extends through the (filled) space that is
adjacent to the electrode. In the case of a capacitor, the electrode surface generates according to its potential an electric field in the space that is adjacent to the electrode surface, which stores energy.

[0044] In the case of an electromechanical resonator instead of the capacitor, the electrode surface generates according to the signal applied thereto an electric field in a piezoelectric, which is in the space that is adjacent to the electrode surface. Here, the electrode surface is designed to act together with the piezoelectric to convert electrical energy into acoustic energy, which is transmitted or stored in the piezoelectric. The electrode surface forms a component part of a frequency-selective component integrated in the filter structure, it being possible, for example, for the frequency-selective component to be formed as a capacitor or as an electromechanical resonator.

[0045] A portion of the electrically insulating material, for example, of the main filter structure body, forms a dielectric layer of the capacitor. Here, the electrically insulating main filter structure body forms a dielectric of the capacitor, in order to increase the permittivity of the capacitor in comparison with a capacitor in a vacuum.

[0046] Alternatively, a portion of the electrically insulating main filter structure body forms a piezoelectric body of the electromechanical resonator. As a result, the portion of the electrically insulating main filter structure body is formed as an electromechanical resonator.

[0047] The two aforementioned possibilities may also be used in combination with one another. In both cases, the main filter structure body is given a further function in addition to the function as an electrical insulator, in that the portion of the electrically insulating main filter structure body forms part of a frequency-selective component. Here, the frequency-selective component is, for example, a capacitor or an electromechanical resonator. The electromechanical resonator may be formed as an oscillating crystal, as a SAW filter or as a BAW filter.

[0048] The at least one electrically conducting surface of the filter structure forms multi-electrode surfaces of the capacitor of the filter structure. The electrode surfaces in one embodiment have two different associated polarities of the capacitor, are not directly connected to one another in an electrically conducting manner, and are, for example, designed to generate an electric field in the intermediate space between the electrode surfaces when a voltage is applied to the capacitor. Furthermore, it is provided that the multiple electrode surfaces extend plane-parallel to one another. The leadthrough of the filter structure also includes at least one connecting portion that extends from one of the electrode surfaces to at least one further electrode surface in order to connect them electrically. The connecting portion corresponds, for example, to a leadthrough on an outer side that is in one embodiment configured as a metal layer. Multiple individual leadthroughs may be provided on the outer side, for example, distributed circumferentially.

[0049] The electrode surfaces electrically connected by the at least one connecting portion belong to the same pole—that is, the same terminal—of the capacitor. The capacitor in one embodiment has at least two different poles, which in each case include multiple electrode surfaces, the electrode surfaces of each pole being electrically connected to one another by respective connecting portions. Electrode surfaces that are formed by the leadthrough form a multi-layered stack. A dielectric is respectively provided between two neighboring electrode surfaces. The dielectric is in one embodiment formed in each case by portions of the main filter structure body. The electrode surfaces are assigned alternately to two different poles of the capacitor and are electrically connected to them, for example, by way of the connecting portions. The electrode surfaces and the connecting portions form an interdigitated structure with two interengaging digits. The structure of the electrode surfaces and of the connecting portions corresponds to the conductor and dielectric structure of a multi-layered capacitor unit. The aforementioned embodiments concern frequency-selective components that are integrated in the filter structure, and, for example, in the main filter structure body.

[0050] In a further embodiment, which is described in the text that follows, the filter structure includes a physically independent frequency-selective component. The frequency-selective component may be a discrete component or an integrated component, the electrical or electronic components of which are accommodated in an individual housing of the component. The physically independent frequency-selective component forms an independent electrical component and has an independent body. The frequency-selective component may, for example, be prefabricated and in one embodiment conforms to a standardized type of construction, for example a type of construction according to a JEDEC standard. For example, the frequency-selective components are SMD components. The at least one electrically conducting surface of the filter structure forms at least one contact area. The component is connected to this contact area. The frequency-selective component is typically formed as a capacitor, as an inductor, as an electromechanical resonator, for example, in the form of a BAW filter, an SAW filter, or an oscillating crystal, or as an integrated filter circuit. The frequency-selective component may, for example, be formed as a capacitor unit, in one embodiment as a capacitor unit with ceramic or mica as the dielectric, for example, as a ceramic capacitor unit. Furthermore, the capacitor unit may be formed as a film capacitor unit, a metal-paper capacitor unit, an electrolyte capacitor unit—for example, as tantalum capacitor unit—or else as a double-layer capacitor unit. When the frequency-selective component is formed as a capacitor, it may include one or more capacitor units, which may be connected to one another. When the frequency-selective component is formed as an inductor, the frequency-selective component includes at least one winding of a coil. For example, the inductor may be formed with or without a core. In one embodiment, the inductor is formed as a wire winding with one or more turns, it being possible for the wire to be provided as bare wire or coated with an electrically insulating enamel layer. Stranded wires may also be used instead of wire. The winding of the inductor is formed, for example, from metal or a metal alloy. The material that provides the winding in one embodiment has a melting point greater than 700°C, greater than 800°C, greater than 1000°C, or greater than 1200°C.

[0051] Furthermore, the physically independent component or frequency-selective component integrated in the filter structure may be formed as an electromechanical resonator. The electromechanical resonator includes a piezoelectric body on which electrodes are formed. The piezoelectric properties have the effect that electrical energy is converted into acoustic energy, the structure of the electromechanical resonator defining an oscillating mode, for instance surface oscillations or oscillations that propagate through the piezoelectric body. Specific electromechanical resonators are SAW filters,
which are also referred to as acoustic surface filters. Furthermore, the electromechanical resonator may be formed as a BAW filter (bulk acoustic wave filter). Furthermore, the electromechanical resonator may be formed as an oscillating crystal. In the case of the BAW filter and the oscillating crystal, the piezoelectric body is acoustically insulated with respect to a housing of the component.

[0052] Furthermore, the physically independent frequency-selective component may be formed as an integrated filter circuit that integrates multiple individual electrical or electronic components. For example, the integrated filter circuit may include passive components, for instance at least one capacitor unit and at least one inductor, for instance a choke. Furthermore, the integrated filter circuit may include at least one active component, for example a transistor.

[0053] The at least one contact area is part of the filter structure. For example, the contact area is connected to the physically independent frequency-selective component, and consequently forms an electrical connection with the frequency-selective component, which is similarly part of the filter structure.

[0054] The physically independent frequency-selective component includes a connection. The connection is physically connected to the contact area by way of a soldered connection or by means of a press fit. Furthermore, the physically independent frequency-selective component may be inserted into a plug-in connection, the main filter structure body carrying plug-in connection contacts of the plug-in connection. The connection of the frequency-selective component may be directly adjacent to the contact area or be connected to it by way of a material-bonded, electrically conducting connection. The at least one connection of the frequency-selective component is connected to the at least one contact area, which is formed by the cermet, by way of an electrical connection, which may be configured as a material-bonded, positive or nonpositive connection. The at least one connection of the frequency-selective component may be formed as an electrically conducting connection area or as a piece of wire or as a pin.

[0055] According to a specific embodiment, the at least one electrically conducting surface of the filter structure extends parallel or perpendicular to a direction of longitudinal extent of the main filter structure body. The electrically conducting surface may be formed here as at least one electrode surface or as at least one contact area. The direction of longitudinal extent of the main filter structure body corresponds to the path of a perpendicular through a housing wall of the housing in which the electrical contacting arrangement can be fitted. The at least one electrically conducting surface is substantially planar, that is, runs along a plane, or is substantially convex or circular-cylindrical. Furthermore, the electrically conducting surface may run along a portion of a circular cylinder or along a portion of a sphere. In the latter case, the at least one electrically conducting surface has the shape of a spherical cap. The aforementioned forms are the forms of an electrically conducting surface, when there are multiple electrically conducting surfaces each surface having one of these forms.

[0056] A further embodiment provides that the electrical leadthrough of the filter structure includes multiple leadthrough elements. The multiple leadthrough elements in each case form a conducting surface of the filter structure. All of the conducting surfaces of the leadthrough element or the leadthrough elements of the leadthrough may form electrode surfaces or contact areas here. This applies, for example, to end faces or circumferential surfaces of the at least one leadthrough element. The conducting surfaces of at least one of the leadthrough elements consequently form electrode surfaces or contact areas.

[0057] The filter structure may include one or more electrical components, the components being selected from the group comprising a capacitor, an electromechanical resonator or (generally) a frequency-selective component, these components each being formed as described above. These components, which may also be referred to as frequency-selective components, may be physically independent or integrated in the filter structure.

[0058] The filter structure includes one or more frequency-selective components. In a topological respect, the filter structure in one embodiment forms a band-stop filter or a low-pass filter. The filter structure may include a capacitive feedthrough filter, a parallel bypass capacitor, a series filter inductor, an LC parallel resonant circuit, an LC series resonant circuit, a throughput filter in T connection or in π connection, an electromechanical bypass filter or an electromechanical series filter. The LC parallel resonant circuit is connected in series with the electrically conducting connection between the interior and the exterior. The LC series resonant circuit is connected as a bypass filter to the electrically conducting connection between the interior and the exterior. The throughput filter in T connection has two series inductors and a parallel capacitor connected in between. The throughput filter in π connection has two parallel capacitors and a series inductor connected in between.

[0059] An electrically conducting securing element may serve for the bypassing, for example in the form of a flange that extends around the electrical feedthrough, or an electrical connection that is designed for being electrically connected to the housing. Furthermore, the housing or a connection to the housing may serve for the bypassing.

[0060] In one embodiment of the contacting arrangement according to the, the electrically conducting surface forms an electrode surface of a capacitor. The electrode surface is provided by a conducting material, for example, a sintered metal or a cermet. The conducting material may furthermore be for example a vapor-deposited, sputtered or electrolytically deposited metallization layer or a printed layer of conducting material. For example, the conducting material may originate from a metallic paste that has been printed on, for example by means of screen printing.

[0061] The capacitor has furthermore a dielectric layer that is formed by a portion of the electrically insulating main filter structure body. The dielectric layer is in one embodiment a ferroelectric, a paraelectric or a dielectric with a relative permittivity of more than 10 or 20. The dielectric layer has a relative permittivity of in one embodiment more than 100, 1000 or 10 000 or 50 000. Ferroelectrics or paraelectrics are suitable, for example, as the material of the dielectric layer. Examples of ferroelectrics and paraelectrics are barium titanate, lead-zirconate-titanate, or else strontium-bismuth-tantalate, bismuth-titanate, bismuth-lanthanum-titanate, bismuth-titanate-niobate, strontium titanate, barium-strontium-titanate, sodium nitrite, or hexagonal manganates RmOn, where R=Y, Sc, In, Ho, Er, Ym, Yb, Lu, or else strontium titanate, potassium titanate or titanium oxide.

[0062] The dielectric layer is, for example, a ceramic layer. This may be a drawn ceramic layer, produced for example from a ceramic suspension. The ceramic suspension from which the ceramic layer is produced includes paraelectric
and/or ferroelectric substances, for example, as presented above, in the form of powder or granules. The dielectric layer, and, for example, the suspension for the production thereof, may include additives with at least one of the following substances: magnesium, cobalt, strontium, niobium and zirconium. The drawn ceramic layer may be obtained by drawing out a slip or the suspension into a ceramic layer, which is created as a green film or green blank. If appropriate, the ceramic layer may be rolled during, before or after the drawing.

[0063] A further embodiment of the contacting arrangement concerns a configuration of the at least one frequency-selective component as a component that is integrated in the main filter structure body or is formed as one part with it. The electrically conducting surfaces are provided multiply in the filter structure, forming multiple electrode surfaces of a frequency-selective component, for example, a capacitor. The multiple electrode surfaces run parallel to one another. A first group of the electrode surfaces is connected to one another in an electrically conducting manner, and a second group of the electrode surfaces is connected to one another in an electrically conducting manner. As a result, the capacitor is provided as a multilayer capacitor unit. If a dielectric layer is adjacent to at least one of the electrode surfaces, a capacitor unit integrated in the main filter structure body is provided. If a piezoelectric layer is adjacent to at least one of the electrode surfaces, a piezoelectric component, for example, an electromechanical resonator, is provided as the frequency-selective component.

[0064] According to a further aspect, the electrically conducting element of the electrical feedthrough is connected in a material-bonded manner to the main feedthrough body for the hermetic sealing. Moreover, the leadthrough of the filter structure is connected in a material-bonded manner to the main filter structure body, for example, by joint sintering. The leadthrough body and the at least one conducting element and also the main filter structure body and the at least one leadthrough are in each case connected to one another in a material-bonded manner, for example, by a material-bonded sintered connection. The respective main body and the at least one conducting element or the leadthrough may furthermore be connected to one another in a material-bonded manner via an electrically conducting solder connection or via a glass solder connection. For example, a hard-soldered connection may connect the respective main body to the at least one conducting element or the leadthrough in a material-bonded manner.

[0065] Furthermore, one embodiment concerns a medically implantable device, for example, a pacemaker or a defibrillator, the medically implantable device having at least one contacting arrangement according to one embodiment. The contacting arrangement is fitted in the housing of the medically implantable device. The tangential extent of the electrical feedthrough corresponds to the circumferential shape of the housing.

[0066] The medically implantable device according to one embodiment provides that the electrical feedthrough is fitted in the housing, in one embodiment by means of a holding element. The holding element includes a flange. The holding element surrounds the electrical feedthrough, for example, circumferentially. The filter structure extends away from the electrical feedthrough. The filter structure protrudes at least partially into the interior.

[0067] For example, one embodiment may be realized by means of a housing for such a medically implantable device. The housing includes at least one contacting arrangement according to one embodiment. The housing and the device have an interior, the housing and the device enclosing the interior.

[0068] Finally, one embodiment is put into practice by means of a method for producing a contacting arrangement according to one embodiment for a medically implantable device. The method includes at least the following steps a)-e).

[0069] A step a) concerns the creation of a green feedthrough blank with a structure of an electrically insulating material to form a main feedthrough body and a structure of a metal- or cermet-containing material to form at least one conducting element within the main feedthrough body. The green feedthrough blank is therefore configured in such a way that it is suitable for forming an electrical feedthrough as described here, for example, after carrying out step b).

[0070] A step b) concerns the firing of the green feedthrough blank. In this way, the electrical feedthrough is created from the green feedthrough blank.

[0071] A step c) concerns the creation of a green filter structure blank with a structure of an electrically insulating material to form a main filter structure body and a structure of a metal- or cermet-containing material to form at least one electrically conducting surface, a conducting portion and/or a leadthrough within the main filter structure body. The green filter structure blank is therefore configured in such a way that it is suitable for forming a filter structure as described here, for example, after carrying out step d).

[0072] A step d) concerns the firing of the green filter structure blank. In this way, the filter structure is created from the green filter structure blank.

[0073] A step e) concerns the arranging of the filter structure on an end face of the feedthrough. Furthermore, in step e), at least one electrical surface connection is established between the filter structure and the feedthrough. The electrical surface connection thus established corresponds to the surface connection described herein.

[0074] Steps a) and c), which concern the creation of a green feedthrough blank and a green filter structure blank, include the provision of a powder from electrically insulating material and the adding of a binder to the powder. The powder may be homogenized before or after the adding of the binder, for example, if the powder includes multiple materials. A suspension is prepared from the powder and the binder. If a capacitor integrated in the main filter structure body is to be provided in the filter structure, the powder of electrically insulating material includes at least one dielectric and, for example, paramagnetic or ferromagnetic material, for instance titanium dioxide or barium titanate. Furthermore, additives of magnesium, cobalt, strontium, niobium or zirconium may be added to the powder or the suspension, in one embodiment before the homogenization. For example, steps that are used for producing ceramic capacitor units may be applied.

[0075] An embodiment of the method provides that the conducting material that is provided for forming the conducting surface is arranged in a layer structure. The suspension is formed in multiple layers, which form the at least one body. The layers are in each case printed with the electrically conducting material, the electrically conducting material being in the form of a paste. The layers are in one embodiment printed on in areas that are offset alternately in relation to one another.
The layers are created, for example, as a ceramic film. The printed layers are pressed before they are cut up into a multiplicity of filter structures. If the layers are created as a ceramic film, pieces of ceramic film are obtained as filter structures by the cutting up. Before the firing, and, for example, after the cutting up, a binder contained in the suspension is removed.

[0076] The creation of the green filter structure blank may include a step of film drawing, in which the suspension and the electrically insulating material are drawn into at least one ceramic film. This forms the dielectric layer of a capacitor unit, which is provided by the filter structure. After the film drawing, the electrically insulating material, that is, the ceramic film, is printed with an electrically conducting material, for example, with a metallic paste. The printed metallic paste is intended to form the electrically conducting surfaces, and, for example, the electrode surfaces, of the capacitor after the firing. To form the capacitor unit as a multilayer structure, the metallic paste is printed in layers that are offset alternately in relation to one another. After a following step of connecting the layers, an interdigitated structure with interengaging digits is obtained, as used in the case of multilayer capacitor units. A metalizing step, which is carried out after the firing, has the effect that the layers are connected perpendicularly to the path of the layers by means of a metalization layer. The metallic paste is applied for example by screen printing, in one embodiment to the drawn ceramic film before it is fired. The electrically conducting material is, for example, a metal- or cermet-containing material, in one embodiment in paste form. The electrically conducting material or the metal- or cermet-containing material is, for example, the material that is transformed by the firing step d) into electrically conducting structures, and, for example, surfaces. Instead of printing the electrically insulating material with metallic paste, the electrically conducting material may be galvanically deposited.

[0077] The drawn ceramic films printed with the metallic paste are stacked one on top of the other. The stacking has the effect that the surfaces provided by the metallic paste are arranged in relation to one another, in one embodiment as alternately offset surfaces. A multilayer structure is obtained from the multiple stacked and printed ceramic films. The stacked ceramic films are pressed, whereby they are compacted. The stacked ceramic films are also cut up, in one embodiment after the pressing. The pieces of ceramic film obtained by the cutting up are freed of the binder. The structure of the pieces of ceramic film corresponds to the configuration of the filter structure, the pieces of ceramic film that are still provided as a green blank being transformed into the filter structure by the firing process. The pieces of ceramic film are fired in step d). The temperature used in step d) may be up to 1200°C, 1300°C or 1500°C and is up to 1400°C. These temperatures are also used in step b). The green feedthrough blanks and the pieces of ceramic film that represent the green blanks of the filter structure may be fired in the same firing process; in this case, steps b) and d) coincide.

[0078] Step d) (and step b)) produces the desired electrical properties. For example, the temperature profile and the duration of step d) are set such that the dielectric layer has the desired permittivity. For example, step d) is set up in such a way that the structure of electrically insulating material of the green filter structure blank forms a paramagnetic or ferromagnetic structure. The paramagnetic or ferromagnetic structure is in one embodiment a layer or forms a multiplicity of layers that are stacked and parallel to one another, which has or have a constant thickness. This layer or these layers are in one embodiment planar.

[0079] An embodiment of the method provides that the at least one electrical surface connection is established by means of a surface soldering process, the electrical surface connection is established by means of adhesive bonding, using an electrically conductive adhesive, or by means of a welding process. As a result, the fired filter structure is electrically connected to the fired feedthrough. For example, the fired conducting elements of the feedthrough are connected to the fired leadthroughs of the filter structure.

[0080] For example, for more complex configurations of the filter structure, for instance a multi-layered structure, connecting portions are created. These connect components of the filter structure, and, for example, parts of components. For example, according to the, connecting portions that connect at least two electrically conducting surfaces are created. In order to form a capacitor that includes one or more electrically conducting surfaces that are formed from electrically conducting material in the filter structure, connecting portions may be created. These electrically conducting surfaces are arranged in electric contact with electrically conducting surfaces. For example, for a capacitor within the filter structure, two connecting portions may be provided on the filter structure. The connecting portions may be arranged on an outer surface, for example, on a side surface of the filter structure. The electrically conducting surfaces may be subdivided into two groups, so that an alternating structure is obtained. Each connecting portion connects the conducting surfaces of one of the groups, for example, on side surfaces of the conducting surfaces. The connecting portions may be formed as electrically conducting material in the form of a green blank and in this form directly contact the material for the forming of a conducting surface. The connecting portions may also be applied to the fired main filter structure body by means of vapor depositing, sputtering, chemical or electrochemical depositing, applying a conducting adhesive or by soldering or welding. In the latter case, the connecting portions are applied to a circumferential surface of the main filter structure body and brought into direct contact with the at least one electrically conducting surface. The electrically conducting surface extends up to the outer circumferential surface of the filter structure. The connecting portions may be regarded as a leadthrough of the filter structure. The connecting portions may be used for the bypassing of interfering AC signals.

[0081] One embodiment provides that the green filter structure blank is created by preparing a suspension that contains at least one dielectric, and, for example, a paraelectric or ferroelectric material. For example, the dielectric, paraelectric or ferroelectric materials described herein may be used. The suspension is prepared by using a binder, as described above. The suspension is formed into at least one body, for example, by film drawing, as described herein. Furthermore, as already stated herein, the at least one body is printed with a paste that contains electrically conductive material. The method also provides firing of the printed body in order to create the filter structure. The firing is carried out by step d).

[0082] A holding element may be created by shaping a green holding element blank around the feedthrough or around the green feedthrough blank. In the latter case, the green holding element blank and the green feedthrough blank are fired together, and if appropriate are pressed together in advance. The green holding element blank may also be pres-
intered before it is arranged around the green feedthrough blank. The green holding element blank may be produced from electrically conducting or electrically insulating material.

[0083] The component of the filter structure is either sintered together with at least one of the green blanks as a component integrated in the filter structure, or the component is fitted as a physically independent component after all of the sintering steps have been completed. The latter possibility is used if the frequency-selective component is not suitable for high temperatures and the exposure of the components to the sintering temperature would destroy or damage the component.

[0084] The proposed electrical feedthrough is designed for fitting in a medically implantable device, it being possible for the medically implantable device to be configured, for example, as an active implantable medical device (AIMD) and in one embodiment as a therapeutic system.

[0085] The term a medically implantable device includes in principle any desired device that is designed to carry out at least one medical function and can be introduced into a body tissue of a human or animal user. The medical function may in principle include any desired function selected from the group consisting of a therapeutic function, a diagnostic function and a surgical function. For example, the medical function may include at least one actuator function, in which at least one stimulus is exerted on the body tissue by means of at least one actuator, for example, an electrical stimulus.

[0086] The term active implantable medical device—also referred to as AIMD—includes in principle all medically implantable devices that can conduct electrical signals from a hermetically sealed housing into part of the body tissue of the user and/or receive electrical signals from the part of the body tissue of the user. Thus, the term active implantable medical device includes, for example, pacemakers, cochlear implants, implantable cardioverters/defibrillators, nerve, brain, organ or muscle stimulators and implantable monitoring devices, hearing devices, retinal implants, muscle stimulators, implantable pumps for medicines, artificial hearts, bone growth stimulators, prostate implants, stomach implants, or the like.

[0087] The medically implantable device, for example, the active implantable medical device, has at least one housing, for example, at least one hermetically sealed housing. The housing may in one embodiment enclose at least one electronic system, for example an electronic actuation and/or evaluation system, of the medically implantable device.

[0088] A housing of a medically implantable device is understood within the scope of one embodiment as meaning an element which at least partially encloses at least one functional element of the medically implantable device that is designed for carrying out the at least one medical function or aids the medical function. For example, the housing has at least one interior, which partially or entirely accommodates the functional element. For example, the housing may be designed to offer mechanical protection for the functional element with respect to loads occurring during operation and/or during handling and/or protection for the functional element with respect to environmental influences, such as, for example, influences caused by a body fluid. The housing may, for example, bound and/or close off the medically implantable device from the outside.

[0089] An interior is understood here as meaning a region of the medically implantable device, for example, inside the housing, that can entirely or partially accommodate the functional element and, in an implanted state, does not come into contact with the body tissue and/or with a body fluid. The interior is a cavity that is closed by the housing, or there may be multiple cavities formed in the interior. Alternatively, the interior may be completely hollow, partially hollow or entirely or partially filled, for example by the at least one functional element and/or by at least one filling material, for example at least one casting compound, for example by a casting material in the form of an epoxy resin or a similar material.

[0090] By contrast, an exterior is understood as meaning a region outside the housing. This may, for example, be a region that, in the implanted state, can come into contact with the body tissue and/or a body fluid. Alternatively or in addition, however, the exterior may also be a region or include a region that is accessible only from outside the housing, without necessarily coming into contact with the body tissue and/or the body fluid, for example a region of a connecting element of the medically implantable device that is externally accessible for an electrical connecting element, for example an electrical plug-in connector.

[0091] The housing and/or for example, the electrical feedthrough may, for example, be of a hermetically sealed configuration, so that for example the interior is hermetically sealed with respect to the exterior. Within the scope of one embodiment, the term "hermetically sealed" may illustrate that, when used as intended, moisture and/or gases cannot pass through the hermetically sealed element, or only minimally, within the usual time periods (for example 5-10 years). A physical variable that can for example describe a permeation of gases and/or moisture through a device, for example through the electrical feedthrough and/or the housing, is that known as the leak rate, which can be determined for example by leak tests. Corresponding leak tests can be carried out for example by helium leak testers and/or mass spectrometers and are specified in the standard MIL-STD-883G Method 1014. The maximum permissible helium leak rate is in this case fixed according to the internal volume of the device to be tested. On the basis of the methods specified in MIL-STD-883G Method 1014, in paragraph 3.1, and taking into consideration the volumes and cavities of the devices to be tested that are encountered in the application of one embodiment, these maximum permissible helium leak rates may be for example 1×10⁻⁸ atm·cm⁻²·sec to 1×10⁻⁷ atm·cm⁻²·sec. Within the scope of one embodiment, the term "hermetically sealed" may mean, for example, that the device to be tested (for example the housing and/or the electrical feedthrough or the housing with the electrical feedthrough) has a helium leak rate of less than 1×10⁻⁷ atm·cm⁻²·sec. In one embodiment, the helium leak rate may be less than 1×10⁻⁸ atm·cm⁻²·sec, for example, less than 1×10⁻⁹ atm·cm⁻²·sec. For the purpose of standardization, the stated helium leak rates may also be converted into the equivalent standard air leak rate. The definition of the equivalent standard air leak rate and the conversion are specified in the standard ISO 3530.

[0092] Electrical feedthroughs and the contacting arrangement according to one embodiment are elements that are designed to create at least one electrical conducting path (that is, an electrically conducting connection) that extends between the interior of the housing and at least one outer part or region outside the housing, for example, in the exterior. The electrical feedthroughs are, for example, elements that are designed on the basis of their resistivity and their structure.
to create the at least one electrical conducting path. Thus, for example, an electrical connection to leads, electrodes and sensors arranged outside the housing is made possible. [0093] In the case of customary medical implantable devices, a housing is generally provided and may have on one side a head part, also known as a header or connector, which may carry connection sockets for the connection of supply leads, also known as electrode leads or leads. The connection sockets have for example electrical contacts, which serve the purpose of connecting the supply leads electrically to an electronic control system inside the housing of the medical device. Where the electrical connection enters the housing of the medical device, an electrical feedthrough is usually provided, fitted in hermetically sealing manner in a corresponding housing opening, in one embodiment the electrical feedthrough of the contacting arrangement. The electrical feedthrough may be fitted in the housing in a sealed manner by means of a holding element.

[0094] On account of the type of use of medically implantable devices, their hermetic sealing and biocompatibility is generally one of the primary requirements. The medically implantable device proposed here according to one embodiment may, for example, be fitted into a body of a human or animal user, for example, a patient. As a result, the medically implantable device is generally exposed to a fluid of a body tissue of the body. Consequently, it is generally important that neither a body fluid penetrates into the medically implantable device nor fluids escape from the medically implantable device. In order to ensure this, the housing of the medically implantable device, and consequently also the electrical feedthrough, should have an impermeability that is as complete as possible, for example, with respect to body fluids.

[0095] Furthermore, the electrical feedthrough should ensure a high electrical insulation between the at least one conducting element and the housing and/or, if multiple conducting elements are provided, between the conducting elements. In this respect, insulation resistances of at least several Mohms, for example, more than 20 Mohms, are achieved, and low leakage currents, which may, for example, be less than 10 pA. Furthermore, if multiple conducting elements are provided, the crosstalk and the electromagnetic coupling between the individual conducting elements in one embodiment lie below medically prescribed thresholds.

[0096] The electrical feedthrough disclosed according to one embodiment, for example, suitable for the stated applications. Furthermore, the electrical feedthrough may also be used in further-reaching applications that make special demands on the biocompatibility, sealing and stability with respect to corrosion.

[0097] The electrical feedthrough according to one embodiment may, for example, satisfy the aforementioned sealing requirements and/or the aforementioned insulating requirements.

[0098] As stated above, the electrical feedthrough has at least one electrically insulating main feedthrough body. The main feedthrough body should be understood as meaning an element that performs a mechanical holding function in the electrical feedthrough, for example in that the main feedthrough body directly or indirectly holds or carries the at least one conducting element. For example, the at least one conducting element may be completely or partially embedded directly or indirectly in the main feedthrough body, for example, by a material-bonded connection between the main feedthrough body and the conducting element and in one embodiment by a co-sintering of the main feedthrough body and the conducting element. The main feedthrough body may, for example, have at least one side that is facing the interior and at least one side that is facing the exterior and/or is accessible from the exterior. These properties also apply to the main filter structure body that holds or carries the leadthrough. The leadthrough of the main filter structure body takes the place of the conducting element of the main feedthrough body.

[0099] As stated above, both main bodies, that is, the main filter structure body and the main feedthrough body, are of an electrically insulating configuration. This means that the two main bodies are each produced completely, or at least in certain regions, from at least one electrically insulating material. An electrically insulating material should be understood in this case as meaning a material that has a resistivity of at least 10^7 Ohms*m, for example, of at least 10^8 Ohms*m, in one embodiment of at least 10^9 Ohms*m and of at least 1011 Ohms*m. For example, the main feedthrough body may be configured in such a way that, as stated above, a flow of current between the conducting element and the housing and/or between multiple conducting elements is at least largely prevented, for example in that the aforementioned resistances between the conducting element and the housing are realized. For example, the main body may include at least one ceramic material. This also applies to the main filter structure body, in the case of which a flow of current between the leadthrough and the housing or between leadthroughs is at least largely prevented, for example in that the aforementioned resistances between the leadthrough and the housing are realized.

[0100] A conducting element or electrical conducting element should be understood here as generally meaning an element that is designed to establish an electrical connection between at least two locations and/or at least two elements. For example, the conducting element may include one or more electrical conductors, for example metal conductors. As stated above, within the scope of one embodiment, the conducting element is completely or partially produced from at least one ceramic. In addition, one or more other electrical conductors may also be provided, for example metal conductors. The conducting element may, for example, be configured in the form of one or more connector pins and/or curved conductors. The conducting element may further have on a side of the main feedthrough body and/or of the electrical feedthrough that is facing the interior and/or on a side of the main feedthrough body and/or of the electrical feedthrough that is facing the exterior or is accessible from the exterior one or more connection contacts, for example one or more plug-in connectors, for example one or more connection contacts, that protrude from the main feedthrough body and/or can be electrically contacted in some other way from the interior and/or from the exterior.

[0101] The aforementioned properties also apply to the leadthrough of the filter structure, the leadthrough having for example on a side of the main filter structure body and/or of the filter structure that is facing the interior and/or on a side of the main feedthrough body and/or of the electrical feedthrough that is facing the feedthrough or is accessible from the feedthrough one or more connection contacts, for example one or more connection contacts for surface connections, that protrude from the main filter structure body or can be electrically contacted in some other way from the interior.

[0102] The feedthrough and the filter structure have surface contacts that are each connected by means of a surface con-
connection. Furthermore, the feedthrough may have plug-in connecting elements on a side opposite from the filter structure, for instance on a side facing the exterior. Furthermore, the filter structure may have plug-in connecting elements, for example on a side opposite from the feedthrough, for example at the place at which the contact point is located. The surface connection between the feedthrough and the filter structure is in one embodiment a material-bonded connection, for instance a soldered connection, but may also be formed as a positive and/or nonpositive connection, for instance by a plug-in connection. In the latter case, the filter structure and the feedthrough may be fitted together, the filter structure having plug-in elements on the side facing the feedthrough and the feedthrough having plug-in elements complementing them on an end face that is facing the filter structure.

[0103] The at least one conducting element of the feedthrough may together with the leadthrough of the filter structure establish the electrically conducting connection between the interior and the exterior in various ways. For example, the conducting element may extend from at least one portion of the conducting element arranged on the end face of the main feedthrough body to at least one on the side facing the exterior or the side accessible from the exterior. However, other arrangements are also possible in principle. Thus, for example, the conducting element may also include a plurality of part connecting elements connected to one another in an electrically conducting manner.

[0104] Furthermore, the conducting element may extend into the interior, into the main filter structure body and/or into the exterior. For example, the conducting element may have at least one region arranged in the interior and/or at least one region arranged in the exterior, it being possible for example for the regions to be electrically connected to one another. The leadthrough may extend completely or in conducting portions from the end face of the feedthrough that is facing the interior to a surface of the filter structure on which a contact point is provided, for example, to a side of the filter structure that is opposite from the end face.

[0105] The at least one conducting element of the feedthrough may have on a side of the main feedthrough body and/or of the electrical feedthrough that is facing the filter element and/or on a side of the main feedthrough body and/or of the electrical feedthrough that is facing the exterior or is accessible from the exterior at least one electrical connecting medium and/or be connected to such an electrical connecting element. For example, as described above, one or more plug-in connectors, for instance contact springs, may be respectively provided on one or both of the sides mentioned. In one embodiment, one or more contact areas or other types of electrical connecting elements are provided on the sides of the filter structure and of the feedthrough that are facing one another. The conducting elements of the leadthrough of the filter structure should be permanently connectable to the conducting element of the feedthrough. The connecting elements facing the exterior should be biocompatible and should be permanently connectable to the at least one conducting element.

[0106] The electrically insulating main feedthrough body may, for example, support the at least one conducting element. Furthermore, the electrically insulating main filter structure body may, for example, support the at least one leadthrough. As stated above, the material of the main feedthrough body and the material of the main filter structure body should in one embodiment be biocompatible and should have a sufficiently high insulation resistance. It has been found to be advantageous for the main feedthrough body according to one embodiment if it includes one or more materials selected from the group consisting of: aluminium oxide (Al₂O₃), zirconium dioxide (ZrO₂), alumina toughened zirconium oxide (ZTA), zirconia toughened aluminium oxide (ZTA—zirconia toughened aluminium—Al₂O₃), yttrium toughened zirconium oxide (Y-TZP), aluminium nitride (AlN), magnesium oxide (MgO), piezoceramic, barium (Zr₂, Ti)oxide, barium(Ce, Ti)oxide and sodium-potassium niobate. The materials may also, for example, be provided as material compositions. The material of the main feedthrough body may be a paraelectric or ferroelectric material, as described herein, for example, the material of the main filter structure body. Similarly, the main filter structure body may include one or more of the aforementioned materials. If it is provided that a portion of the main filter structure body is intended to form a dielectric layer of a capacitor integrated in the filter structure, a material with a permittivity of more than 10 or 20 is then used, in one embodiment a paraelectric or ferroelectric material.

[0107] A peripheral body, which is also referred to as a holding element, reaches around the main feedthrough body and serves as a connecting element in relation to the housing of the implantable device. The materials of the holding element must be biocompatible, easily processable, corrosion-resistant and permanently connectable in a material-bonded manner to the main feedthrough body and the housing. It has been found to be advantageous for the holding element according to one embodiment if it includes at least one of the following metals and/or an alloy on the basis of at least one of the following metals: platinum, iridium, niobium, molybdenum, tantalum, tungsten, titanium, cobalt-chromium alloys or zirconium. The holding element may alternatively include a cermet, this similarly being advantageous with regard to sealing and the production process. In the case of the proposed electrical feedthrough, the at least one conducting element includes at least one cermet. In the case of the proposed filter structure, the at least one leadthrough includes at least one cermet.

[0108] The main feedthrough or filter structure body may, for example, be produced entirely or partially from one or more sinterable materials, for example, from one or more ceramic-based sinterable materials. The conducting or elements of the feedthrough and also the leadthroughs of the filter structure may be entirely or partially made up of one or more cermet-based sinterable materials. In addition, as stated above, the at least one conducting element of the feedthrough or the at least one leadthrough of the filter structure may however also have one or more further conductors, for example one or more metal conductors.

[0109] Within the scope of one embodiment, “cermet” is the term used to describe a composite material comprising one or more ceramic materials in at least one metallic matrix or a composite material comprising one or more metallic materials in at least one ceramic matrix. To produce a cermet, it is possible for example to use a mixture of at least one ceramic powder and at least one metallic powder, which may for example be mixed with at least one binder and, if appropriate, at least one solvent. The ceramic powder or powders of the cermet in one embodiment has/have an average grain size of less than 10 μm, less than 5 μm, less than 3 μm. The metallic powder or powders of the cermet in one embodiment has/have an average grain size of less than 15 μm, less than 10 μm, less
than 5 µm. To produce a main filter structure body or main feedthrough body, it is possible for example to use at least one ceramic powder, which may for example be mixed with at least one binder and, if appropriate, at least one solvent. The ceramic powder or powders in one embodiment have/have in this case an average grain size of less than 10 µm (1 µm corresponds to 1x10^{-6} m), less than 5 µm, less than 3 µm. In this case, the median value or d50 value of the grain size distribution is regarded, for example, as the average grain size. The d50 value describes that value for which 50% of the grains of the ceramic powder and/or of the metallic powder are finer and the other 50% are coarser than the d50 value.

Sintering or a sintering process is understood within the scope of one embodiment as generally meaning a method for producing materials or workpieces in which powdered, for example, fine-ground, ceramic and/or metallic substances are heated and thereby bonded. This process may take place without external pressure on the substance to be heated or may, for example, take place under increased pressure on the substance to be heated, for example, under a pressure of at least 2 bar, higher pressures, for example pressures of at least 10 bar, for example, at least 100 bar or even at least 1000 bar. The process may, for example, take place completely or partially at temperatures below the melting temperature of the powdered materials, for example at temperatures of 700°C to 1400°C. The process may, for example, be carried out completely or partially in a tool and/or a mold, so that the sintering process may involve molding. Apart from the powdered materials, a starting material for the sintering process may include further materials, for example one or more binders and/or one or more solvents. The sintering process may take place in one step or else in multiple steps, it being possible for example for the sintering process to be preceded by further steps, for example one or more molding steps and/or one or more debinding steps. The sintering or the sintering process consequently corresponds to a firing process.

In the production of the feedthrough and/or the filter structure there may be used, for example, a method in which firstly at least one green blank is produced, subsequently at least one brown blank is produced from this green blank and subsequently the finished workpiece is produced from the brown blank by performing at least one firing or sintering step on the brown blank. In this case, on the other hand separate green blanks and/or separate brown blanks may be produced for the conducting element and for the leadthrough and for the main feedthrough body and the main filter body, and subsequently connected. Alternatively, however, one or more common green blanks and/or brown blanks may also be produced for the respective main body and the conducting element and the leadthrough. Once again alternatively, firstly separate green blanks may be produced, these green blanks may then be connected and subsequently a common brown blank may be produced from the connected green blank.

A green blank should be understood as meaning generally a preform of a workpiece that includes the starting material, for example the at least one ceramic and/or metallic powder, and furthermore, if appropriate, one or more binder materials and/or one or more solvents. A brown blank should be understood as meaning a preform that is obtained from the green blank by at least one debinding step, for example at least one thermal and/or chemical debinding step, the at least one binder material and/or the at least one solvent being at least partially removed from the preform in the debinding step.

The sintering process, for example, for a cermet, but also for example for the main feedthrough and/or filter structure body, may proceed in a way comparable to a sintering process that is usually used for homogeneous powders. For example, the material may be compacted under high temperature and, if appropriate, high pressure, so that the cermet is almost impermeable, or has an extremely closed porosity. Cerments are generally distinguished by particularly high hardness and wear resistance. As compared with sintered carbide, a conducting element containing cermet or a corresponding leadthrough generally has a higher thermal shock and oxidation resistance and generally a coefficient of thermal expansion that is adapted to a surrounding insulator.

For the feedthrough and/or filter structure according to one embodiment, the at least one ceramic component of the cermet may include, for example, at least one of the following materials: aluminum oxide (Al2O3), zirconium dioxide (ZrO2), alumina toughened zirconium oxide (ZTA), zirconia toughened aluminum oxide (ZTA — zirconia toughened aluminum—Al2O3-ZrO2), yttrium toughened zirconium oxide (Y-TZP), aluminum nitride (AlN), magnesium oxide (MgO), piezoceramic, hafnium(Zr, Ti)oxide, hafnium(Ce, Ti)oxide, or sodium-potassium niobate.

For the feedthrough according to one embodiment, the at least one metallic component of the cermet may include, for example at least one of the following metals and/or an alloy on the basis of at least one of the following metals: platinum, iridium, niobium, molybdenum, tantalum, tungsten, titanium, cobalt or zirconium. An electrically conductive connection generally occurs in the cermet wherever the metal content lies above what is known as the percolation threshold, at which the metal particles in the sintered cermet are connected to one another at least at points, so that an electrical conduction is made possible. Experience shows that, depending on the material selection, for this purpose the metal content should be 25% by volume and more, in one embodiment 32% by volume, for example, more than 38% by volume.

For the purposes of one embodiment, the terms “comprising a cermet” and “cermet-containing” are used synonymously. Consequently, both terms refer to a property of an element in which the element is cermet-containing. This term also covers the variant of an embodiment where an element, for example the conducting element, consists of a cermet, that is to say is made up completely of a cermet. The electrically conducting surface may be provided by applying or printing a metallic paste. Alternatively, the electrically conducting surface may be provided as cermet. In the latter case, a green blank of the electrically conducting surface is provided as a green cermet-containing blank.

In one embodiment, both the at least one conducting element, the leadthrough, and the respective main bodies (that is, the main feedthrough body and the main filter structure body) may have one or more constituents that are produced or can be produced in a sintering process, or at least one conducting element, the leadthrough and the main bodies may both be produced or be able to be produced in a sintering process. For example, on the one hand the main feedthrough body and the conducting element and on the other hand the main filter structure body and the leadthrough may be produced or able to be produced in a co-sintering process, that is
to say a process of simultaneous sintering of these elements. For example, on the one hand the conducting element and the main feedthrough body and on the other hand the leadthrough and the main filter structure body may in each case have one or more ceramic constituents that are produced, and in one embodiment compacted, in the course of at least one sintering process.

[0118] For example, a green main body blank (that is, a green blank of the main feedthrough body or a green blank of the main filter structure body) may be produced from a non-conducting material or an insulating material composition. This may take place for example by pressing of the material composition in a mold. For this purpose, the insulating material composition is in one embodiment a powder mass that has at least a minimum cohesion of the powder particles. The production of a corresponding green blank in this case takes place for example by pressing powder masses, or by shaping by plastic molding or by casting and subsequent drying.

[0119] Such method steps may also be used to shape at least one green cermet-containing conducting element blank or green leadthrough blank or a green blank of a conducting surface of the filter structure. In this respect, it may be provided for example that the powder that is pressed to form the green blank mentioned is cermet-containing or consists of a cermet or that at least includes a starting material for a cermet. After that, the two green blanks—the green main body blank and the green cermet-containing blank—may be brought together. The production of the green cermet-containing blank and the green main body blank surrounding the latter may also take place simultaneously, for example by multicomponent injection molding, coextrusion, etc., so that subsequent connection is no longer necessary.

[0120] During the sintering or firing of the green blanks, they are in one embodiment subjected to a heat treatment, which lies below the melting temperature of the powder particles. There is thus generally a compaction of the material, with an accompanying clear reduction in the porosity and the volume of the green blanks. One special feature of the method is consequently that the main body and the conducting element located therein or the leadthrough located therein or the conducting surface located therein can in one embodiment be sintered together. Accordingly, there is no longer any need thereafter for the elements to be connected.

[0121] The sintering has the effect that the conducting element is connected to the main feedthrough body and the leadthrough or the conducting surface is connected to the main filter structure body, in one embodiment in a nonpositive and/or positive and/or material-bonded manner. As a result, a hermetic integration of the conducting element in the main feedthrough body is achieved. In one embodiment, no subsequent soldering or welding of the conducting element or the leadthrough in the main body concerned is required any longer. Rather, the joint sintering and the use of a green cermet-containing blank have the effect that a hermetically sealing connection is achieved between the main body concerned and the conducting element of the leadthrough.

[0122] An advantageous configuration of the method according to one embodiment is distinguished by the fact that the sintering includes only partial sintering of a green main body blank, it being possible for this partial sintering to bring about and/or include for example the debinding step described above. In the course of this only partial sintering, the green blank is in one embodiment heat-treated. Generally, a shrinkage of the volume of the green blank thereby already takes place. However, the volume of the green blank generally does not reach this final stage. Rather, a further heat treatment—a final sintering—in which the green blank or blanks is/are shrank to their final size is generally still needed. Within the scope of this variant of an embodiment, the green blank is in one embodiment only partially sintered, in order already to achieve a certain strength, in order that the green blank can be handled more easily.

[0123] The starting material that is used for producing at least one green blank of the conducting element, the leadthrough, the conducting surface and/or at least one green blank of the main body concerned may, be a dry powder or include a dry powder, the dry powder being pressed in the dry state to form a green blank and having sufficient adhesion to retain its form as a pressed green blank. Optionally, however, one or more further components may be included in the starting material in addition to the at least one powder, for example, as stated above, one or more binders and/or one or more solvents. Such binders and/or solvents, for example organic and/or inorganic binders and/or solvents, are known in principle to a person skilled in the art and are for example commercially available. For example, the starting material may include one or more slips or be a slip. Within the scope of one embodiment a slip is a suspension of particles of a powder of one or more materials in a liquid binder, and if appropriate in a water-based or organic binder. A slip has a high viscosity and can be formed into a green blank in a simple way without high pressure, for instance by casting or injection molding or by plastic molding.

[0124] The sintering process, which is generally carried out under the melting temperature of the ceramic, cermet or metal materials that are used, but in individual cases also just above the melting temperature of the low-melting component of a multi-component mixture, usually the metal component, leads in the case of green blanks comprising slips to the binder slowly diffusing out from the slips. Overly rapid heating leads to a rapid increase in volume of the binder by transformation into the gaseous phase and to destruction of the green blank or to the formation of undesired flaws in the workpiece.

[0125] Thermoplastic or thermosetting polymers, waxes, thermogelling substances or surface-active substances may be used for example as binders. These may be used on their own or as binder mixtures comprising multiple such components. If individual elements or all of the elements of the feedthrough (green main feedthrough body blank, green conducting element blank, feedthrough blank) or of the filter structure (green main filter structure body blank, green blank of the leadthrough, green blank of the conducting surface, green filter structure blank) are created in the course of an extrusion process, the composition of the binder should be such that the strand of the elements that is extruded through the die is dimensionally stable to the extent that the form dictated by the die can be readily maintained. Suitable binders are known to a person skilled in the art.

[0126] Cermets are generally distinguished by particularly high hardness and wear resistance. The “cermets” and/or “cermet-containing” substances may in particular be or include carbide-related cutting materials, which can however manage without the carbide tungsten carbide and can be prepared for example powder-metallurgically. A sintering process for cermets and/or the cermet-containing conducting element may, for example, proceed as in the case of homogeneous powders, with the only difference being that the metal is generally compacted more strongly than the ceramic
under the same pressing force. As compared with sintered carbides, the cermet-containing conducting element generally has a higher thermal shock and oxidation resistance. As stated above, the ceramic components may be for example aluminum oxide (Al₂O₃) and/or zirconium dioxide (ZrO₂), while niobium, molybdenum, titanium, cobalt, zirconium and chromium come into consideration as metallic components.

[0127] In order to integrate the electrical feedthrough in the housing of a pacemaker, the electrical feedthrough may have a holding element. This holding element is arranged like a collar or circumferentially around the main feedthrough body. Like a collar or circumferentially is the term used for example, for the form of a sphere with a radially outwardly extending bead. The holding element encloses the main feedthrough body, fully circumferentially. The holding element serves for the nonpositive and/or positive connection to the housing. In this case, a fluid-tight connection must be produced between the holding element and the housing. In one way of doing this, the electrical feedthrough has a holding element that includes the cermet. The cermet-containing holding element can be connected to the housing of the medically implantable device easily, permanently and with hermetic sealing with respect to the housing. In a further advantageous embodiment, it is provided that the holding element not only includes a cermet but consists of a cermet. Furthermore, it is conceivable that the conducting element or the leadthrough or the electrical surface on the one hand and the holding element on the other hand are of one and the same material. In the case of this variant, the same materials are used for the conducting element and for the leadthrough and for the electrically conducting surface and the holding element. For example, the material concerned is a resistant, conductive and biocompatible cermet. Since not only the holding element on the one hand but also the conducting element, the leadthrough or the electrically conducting surface on the other hand are still connected to metallic components, both have to meet corresponding prerequisites for welding or soldering. If a cermet that meets the aforementioned prerequisites is found, it can be used not only for the holding element but also for the conducting element, the leadthrough and the conducting surface, in order in this way to obtain a particularly inexpensive electrical feedthrough.

[0128] The main feedthrough body or the main filter structure body may also be regarded from an electrical viewpoint as an insulating element that is electrically insulating. The main bodies are formed from an electrically insulating material, in one embodiment from an electrically insulating material composition. The main bodies are designed to electrically insulate the conducting components that are carrying the respective main body from the housing or from the other articles of the medically implantable device. Electrical signals that pass through the leadthrough and through the conducting element are not to be weakened or short-circuited by a contact with the housing of the implantable device. In addition, the main feedthrough body must include a biocompatible composition, in order to be medially implanted. It is therefore preferred in one embodiment if the main feedthrough body or else the main filter structure body consists of a glass-ceramic or glass-like material. It has been found to be particularly preferred in one embodiment if the insulating material composition of the two main bodies is at least one from the group comprising aluminum oxide (Al₂O₃), magnesium oxide (MgO), zirconium oxide (ZrO₂), aluminum titanate (Al₆TiO₁₇) and piezoceramics. Of these, aluminum oxide has a high electrical resistance and low dielectric losses. In addition, these properties are complemented by high thermal resistance, and also good biocompatibility

[0129] A further advantageous configuration of the contacting arrangement according to one embodiment is distinguished by the fact that the electrical feedthrough is surrounded by a holding element that has at least one flange, with, for example, the flange being metallically conducting. The flange serves the purpose of sealing the electrical feedthrough with respect to a housing of the implantable device. The electrical feedthrough is held in the implantable device by the holding element. In the variant of an embodiment described here, the holding element has at least one flange on an outer side. These flanges form a bearing, in which the covers of the medically implantable device can engage, in one embodiment can engage in a sealing manner. Consequently, the holding element with the connected flanges may have a U-shaped or I-shaped cross section. The integration of at least one flange in the holding element has the effect of ensuring a secure, shockproof and permanent integration of the electrical feedthrough in the implantable device. In addition, the flanges may be configured in such a way that the covers of the implantable device are connected to the holding element in a clip-like, nonpositive and/or positive manner.

[0130] A further advantageous configuration of the electrical feedthrough according to one embodiment is distinguished by the fact that the at least one flange includes a cermet. Within the scope of this variant of the embodiment, both the holding element and the flange include a cermet. In one embodiment, the flange and the holding element are of one and the same material. The configuration of the flange as cermet allows it to be sintered together with the main body and the conducting element as part of the holding element in a simple and inexpensive way in the course of the method still to be described.

[0131] Part of one embodiment is likewise a medically implantable device, for example, a pacemaker or defibrillator, with a contacting arrangement according to at least one of the previously described claims. It goes without saying that features and details that have been described in conjunction with the electrical feedthrough and/or the method also apply here in conjunction with the medically implantable device.

[0132] Features and properties that are described in conjunction with the contacting arrangement also apply to the method according to one embodiment, and vice versa.

[0133] The method according to one embodiment provides that not only the main bodies but also the conducting element and also the leadthrough and the conducting surface have ceramic constituents that are worked in the course of a sintering process. A green main filter structure body blank or a green main feedthrough body blank is created from an insulating material composition. This may take place by the material composition being pressed together in a mold. For this purpose, the insulating material composition is a powder mass that has at least a minimum cohesion of the powder particles. This is usually realized by a grain size of the powder particles not exceeding 0.5 mm. However, the average grain size is in one embodiment not greater than 10 μm. The production of a green blank takes place here either by pressing powder masses, or by shaping and subsequent drying. Such method steps are also used to shape the green cermet-con-
taining conducting element blank or other green cermet-contain-
ting blanks. In this respect, it is provided that the powder 
that is pressed to form the green conducting element blank, 
the green leadthrough blank or the green blank of the con-
ducting surface is cermet-containing or consists of a cermet. 
After that, the green blanks—for example, the green conduction-
element or leadthrough blank and the green main body 
blank concerned—are in one embodiment brought together.
This is followed by firing of the two green blanks—also 
referred to as sintering. In the course of the sintering or firing, 
the green blanks are thereby subjected to a heat treatment, 
which lies below the melting temperature of the powder 
particles of the green blank. A clear reduction in the porosity 
and the volume of the green blanks occurs. The special feature 
according to one embodiment of the method is consequently 
that the main body and the conducting element are fired 
together and the conducting element is created with at least 
one conducting surface. There is no longer any need for the 
two elements to be connected thereafter, and for example, a conducting surface does not have to be created in a further 
step.

The firing process has the effect that the conducting 
element is connected to the main body in a nonpositive and/or 
positive and/or material-bonded manner. As a result, a her-
metic integration of the conducting element or the leadthrough in the main body concerned is achieved. No 
subsequent soldering or welding of the conducting element or 
the leadthrough in the main body concerned is required any 
longer. Rather, the joint firing and the use of a green cermet-
containing blank, that is, the green conducting element blank 
or the green leadthrough blank, have the effect that a hermeta-
cally sealing connection is achieved between the conducting 
element or the leadthrough and the main body concerned.

An advantageous configuration of the method 
according to one embodiment is distinguished by the fact that 
the green main body blanks are firstly sintered only partially. 
In the course of this only partial sintering, the green blank of 
the main body concerned is heat-treated. A shrinkage of 
the volume of the green blank concerned thereby already takes 
place. However, the volume of the green blank does not reach 
its final stage. Rather, a further heat treatment is needed, one 
in which the green main body blank concerned is shrank with 
the green conducting element blank or the green leadthrough 
blank to its final size. Within the scope of this variant of the 
embodiment, the green blank is only partially heat-treated, 
in order already to achieve a certain surface hardness, in order 
that the green blank of the main body concerned can be 
handled more easily. This is appropriate, for example, in 
the case of electrically non-conducting materials or material 
compositions, which can only be pressed into the form of a 
green blank with certain difficulties.

For example, a component of the procedure accord-
ing to one embodiment is referred to as a green blank if not all 
the sintering steps are carried out. Therefore, a presintered 
or initially sintered or heat-treated green blank is referred to as 
a green blank whenever not all of the firing, heat-treated or 
sintering steps have been completed.

A further variant of the embodiment is distinguished 
by the fact that the green conducting element blank or the 
green feedthrough blank is also partially sintered in advance.
As described above in the case of the green main body blank, 
the green conducting element blank may also be partially 
sintered in order to achieve a certain surface stability. It must 
be noted here that, in this variant of the embodiment, the final, 
complete sintering also only takes place in the step of the 
firing step concerned. Consequently, the green conducting 
element blank also only reaches its final size in step b), and the 
green leadthrough blank only reaches its final size in step d).

A further advantageous configuration of the method 
in one embodiment is distinguished by the fact that at least 
one green cermet-containing holding element blank is created 
for a holding element. The green conducting element blank is 
introduced into the green main feedthrough body blank. The 
green main feedthrough body blank is introduced into the 
green holding element blank. The green main feedthrough 
body blank is fired with the at least one green conducting 
element blank and the green holding element blank. A main 
feedthrough body with a conducting element and a holding 
element is obtained.

The special feature of this method step is that the 
green holding element blank is sintered in one step along with 
the green conducting element blank and the green main 
feedthrough body blank. All three green blanks are created, 
then joined together and after that fired or sintered as a unit. 
In one particular variant of the embodiment, the creation of 
the at least one green cermet-containing holding element blank 
may include partial sintering. In this case, it is also again 
provided that the green holding element blank is partially 
sintered, in order to achieve an increased surface stability.

In the text that follows, a specific exemplary 
embodiment of a method for producing a contacting arrange-
ment according to one embodiment is presented.

In the first step, a cermet mass is prepared from 
platinum (Pt) and aluminum oxide (Al₂O₃) with 10% zirconium 
dioxide (ZrO₂). The following starting materials are 
used for this:

40% by volume Pt powder with an average grain 
size of 10 μm

60% by volume Al₂O₃/ZrO₂ powder with a rela-
tive content of 10% ZrO₂ and an average grain size of 1 μm.

The two components were mixed together and with 
water and a binder and were homogenized by a kneading 
process. By analogy with the first step, in a second step a 
ceramic mass was prepared from a powder with an Al₂O₃ 
content of 90% and a ZrO₂ content of 10%. The average grain 
size was approximately 1 μm. The ceramic powder was like-
wise mixed with water and a binder and homogenized. In a 
third step, the ceramic mass prepared in step two, comprising 
aluminum oxide with a content of 10% zirconium dioxide, 
was introduced into a mold of a main body, that is, a main 
feedthrough body. A cermet body produced from the cermet 
mass prepared in the first step, containing a mixture of plati-
num powder and aluminum oxide with a content of 10% 
zirconium dioxide, was introduced as a green blank into an 
opening in the green blank of the main feedthrough body.
Subsequently, the ceramic mass was compacted in the mold. 
After that, the cermet component and the ceramic component 
were debinded at 500° C. and fully sintered at 1650° C.

A filter structure can be produced in the same way. 
Here, the main filter structure body is first created as a green 
blank. Instead of Al₂O₃, at least one paraelectric or ferroelec-
tric material as described above may be used here. In the 
specific exemplary embodiment, barium titanate is used as 
the material for the main filter structure body. The barium 
titanate is provided as a powder that is mixed with a binder. 
This produces a suspension, which is drawn to form a ceramic 
layer. The ceramic layer thus obtained is printed with a silver
paste as a metal paste, in order to provide the conducting surfaces in the green blank. The printed ceramic layer is stacked, one layer on top of the other, thereby obtaining surfaces of the silver paste that are offset alternately in relation to one another. This is followed by a pressing process, by means of which the stacked and printed ceramic layers are compressed. After the pressing process, the pressed ceramic layers are cut up. The pieces of ceramic film produced by the cutting up are freed of the binder. The pieces of ceramic film form filter structures in the state of a green blank. After the removal of the binder, the pieces of ceramic film are sintered or fired. After that, circumferential surfaces of the fired pieces of ceramic film are metalized, in order to create the connecting portions that electrically connect groups of the conducting surfaces. The connecting portions also each form an outer side, respectively connected to the housing or a securing device for the bypassing of interference signals.

After that, the filter structure and the feedthrough are connected to one another, in that the surface connection is provided. The surface connection is created by means of a soldering process. Low-temperature solders, for example, an alloy with gold and tin, may be used inter alia as the solder. A soldered connection allows different thermal expansions of the feedthrough and the filter structure to be compensated. The melting point of the low-temperature solder that is used lies below 300°C or below 350°C. The contacting arrangement thus obtained can be fitted into a housing of a medical device.

In the creation of the main filter structure body, the conducting surfaces are created for example by a screen-printing process, in which metallic paste is applied. The metallic paste, which forms the conducting surfaces, includes a metal or an alloy of which the melting point lies below the maximum sintering temperature or maximum firing temperature. The metallic paste is melted during the firing step d) and forms at least one continuous conducting surface.

FIG. 1 illustrates an overview of a medically implantable device with a contacting arrangement according to one embodiment. The medically implantable device includes a housing, in the interior of which multiple cavities are provided. One cavity offers space for a battery (not represented). In a further cavity, which is adjacent to the cavity, there is an electronic control system. The device includes a header or connector for connecting external electrodes. The space outside the housing is referred to as the exterior, and the space that is enclosed by the housing is referred to as the interior. The device includes a contacting arrangement according to one embodiment, which has an electrical feedthrough and a filter structure adjacent thereto. The contacting arrangement connects the header, which is at the exterior, and the interior. The filter structure is facing the interior, and the electrical feedthrough is facing the exterior. The filter structure and the electrical feedthrough are connected to one another by way of a surface connection, which is provided on the sides of the filter structure and of the electrical feedthrough that are facing one another.

FIG. 2 illustrates an overview of a contacting arrangement according to one embodiment, comprising an electrical feedthrough and a filter structure. The electrical feedthrough has multiple conducting elements, which are in each case separated from one another by the insulating main feedthrough body. The electrically conducting conducting elements are connected in a material-bonded and sealed manner to the insulating main feedthrough body, which circumferentially surrounds the conducting elements.

The upper side of the feedthrough as represented in FIG. 2, that is, the side that is facing away from the filter structure, is intended to be adjacent to the exterior or the header. The side of the feedthrough that is facing the filter structure is facing the interior. Furthermore, this side of the feedthrough is adjoined by the filter structure. The filter structure includes schematically represented leadthroughs, which adjoin the conducting elements of the feedthrough. Furthermore, the filter structure includes schematically represented frequency-selective components in the form of capacitors. These capacitors are connected as bypass capacitors and are in each case connected in series between the leadthroughs and a reference potential, for instance ground (not represented). As a result, high-frequency components of signals that are transmitted from the exterior into the interior by way of the conducting elements and the leadthroughs are conducted to ground. The feedthrough is provided in a circumferential securing element. With the securing element, the contacting arrangement, and, for example, the electrical feedthrough thereof, can be recessed into an opening in a housing.

FIG. 3 illustrates a representation of a filter structure of the contacting arrangement according to one embodiment. For a better overview, the filter structure is illustrated only with a single feedthrough. The filter structure includes electrically conducting surfaces, which are arranged in multiple layers and alternately offset. This produces the electrode structure of a multi-layered capacitor with two interconnecting digits. The electrically conducting surfaces, which are embedded here in a main filter structure body, which is electrically non-conducting and has dielectric properties. The electrode surfaces are divided into two groups, a first group of electrode surfaces being electrically connected to the leadthrough and a group of electrode surfaces being connected to a bypass side. The bypass side provides electrical connections between all of the electrode surfaces of the second group. The bypass side consequently forms a connecting portion to allow all of the electrode surfaces to be contacted at one and the same time. The bypass side is provided circumferentially on an outer side of the filter struc-
FIG. 4 illustrates a contacting arrangement according to the, comprising a feedthrough 330 and a filter structure 350. For a better overview, the feedthrough 330 is illustrated only with one conducting element 310 and the filter structure 350 is illustrated only with one leadthrough 360. In one embodiment, the feedthrough and the filter structure include multiple conducting elements and leadthroughs, for example, equal in number, each conducting element being assigned precisely one leadthrough, respectively connected to one another by way of an individual surface connection.

The contacting arrangement of FIG. 4 illustrates a feedthrough 330 with an electrically conducting conducting element 310 circumferentially surrounded by an electrically non-conducting main feedthrough body 320. The main feedthrough body 320 is held by a circumferential holding element 340. A surface connection 390 in the form of a soldered connection connects the conducting element 310 to the leadthrough 360 of the filter structure 350. The leadthrough 360 is surrounded by a non-conducting main filter structure body. Recessed in the main filter structure body are electrode surfaces, as illustrated in more detail in FIG. 3. When viewed along the leadthrough, the electrode surfaces are connected alternately to the leadthrough 360 and to a connecting portion. The structure of the capacitor corresponds to the structure represented in FIG. 3. At the end of the leadthrough 360 opposite from the surface connection 390, a contact point 364 is provided in the form of a bonding pad. The contact point 364 faces into the interior, for example, into the center thereof, and can be freely contacted from the interior, in one embodiment by means of a surface contact. The contact point 364 of the leadthrough 360 of the filter structure 350 is opposite from an outer contact point or an external connection point 312. The inner contact point 364 and the connection point 312 are electrically connected directly to one another by way of the leadthrough 360 of the filter structure 350 and the conducting element 310 of the feedthrough 330. The conducting element 310 and the leadthrough 360 are connected in series by way of the surface connection 390.

FIG. 5 illustrates an embodiment of the contacting arrangement according to one embodiment, comprising a feedthrough 430 and a filter structure 450 with several possible components. For exemplary purposes, the filter structure 450 is equipped with different components. In FIG. 5, too, only one conducting element 410 and one leadthrough 460 are respectively represented for a better overview. The feedthrough 430 includes a conducting element 410, which is provided in an electrically non-conducting main feedthrough body 420. On the side facing away from the filter structure 450, the one conducting element 410 provides an outer contact point or an external connection point 312. The main feedthrough body 420 is encompassed by an optional securing element, which is illustrated by dashed lines. On the side facing the filter structure 450, an end face of the feedthrough 430, the conducting element 410 provides a first surface contact 414. The first surface contact 414 is connected, in one embodiment in a material-bonded manner, to a second surface contact 462 by way of a surface connection 490 (realized as a soldered connection by means of a solder bead). The surface connection may also be provided in a material-bonded manner, for example by means of a conducting adhesive. The surface connection may furthermore be established in a positive or nonpositive manner, for example by means of a plug-in contact or a (resilient) support contact.

The second surface contact 462 is provided on a side of the filter structure 450 that is facing the feedthrough 430. This side is an end face of the filter structure 450. For example, the second surface contact 462 is provided at an end of the leadthrough 460 that is facing the feedthrough 430.

As a frequency-selective component integrated in the main filter structure body, the filter structure 450 includes a capacitor. This is formed by a first group of electrode surfaces 470 and a second group of electrode surfaces 470'. The first group of electrode surfaces 470 is electrically connected directly to the leadthrough 460 of the filter structure 450. The second group of electrode surfaces 470' is electrically connected directly to a connecting portion 471 of the filter structure 450. The connecting portion 471 is located on a circumferential outer side of the filter structure 450. The connecting portion 471 is a metallization layer and is in one embodiment designed to be connected to the housing or the securing element. The electrode surfaces 470 and 470' are parallel to one another and run perpendicularly in relation to the leadthrough 460. Between the first group and the second group of electrode surfaces 470, 470', which are connected alternately to the leadthrough 460 and the connecting portion 471, are dielectric layers 472, in one embodiment comprising paraelectric or ferroelectric material. The main filter structure body may be formed completely from the material of the dielectric layers 472; portions of the main filter body form the dielectric layers. Alternatively, only the portions of the main filter body that also form dielectric layers 472 between electrode surfaces may be formed from paraelectric or ferroelectric material. The remaining part of the main filter body may be formed from another, non-conducting material. The main feedthrough body 420 may also be formed from another, non-conducting material.

The electrode surfaces 470, 470' and the dielectric layers 472 form a first capacitor, which is connected for the bypassing of high-frequency components from the leadthrough to the connecting portion 470. The first capacitor is connected to a first portion of the leadthrough 460, which is directly connected to the surface connection 490.

A second capacitor is formed by the electrode surface 473, which extends circumferentially around the leadthrough 460. Between the electrode surface 473 and the leadthrough 460, for example, the first portion thereof, there is a cylindrical layer of the main filter structure body. This produces a second capacitor as a frequency-selective component that is integrated in the main filter structure body. The electrode surface 473 is connected to a further connecting portion 471' by way of a radial connection (provided from the same material as the leadthrough 460). This further connecting portion is configured in the same way as the connecting portion 471. The connecting portion 471' may also be formed as one part with the connecting portion of the first capacitor.

A second portion of the leadthrough 460 adjoins the first portion and forms an inductor 474, which is schematically represented and connected in series in the leadthrough 460. Since an inductor 474 transmits low-frequency components, the leadthrough may include such an inductor 474 without impairing its function as an electrical connecting element. The inductor 474 is formed by the material of the leadthrough 460 and forms part of the leadthrough 460. The inductor 474 includes a meandering or helical portion of the leadthrough 460 that is embedded in the main filter structure body. This portion may be surrounded by a ferromagnetic or paramagnetic material that has a high permeability, for
instance μ>100 or 200. Like the main filter structure body, the ferromagnetic or paramagnetic material may be sintered and configured as one part with the remaining main filter structure body. The inductor forms a frequency-selective component that is integrated in the main filter structure body.

[0160] In a modified embodiment, the inductor is formed by a wound wire, which is fitted in series in adjoining portions of the leadthrough. Such an inductor may have a housing of its own, and, for example, a magnetic core. Such an inductor is an example of a frequency-selective component that is physically independent and is connected to the leadthrough by way of connections of its own.

[0161] A third portion of the leadthrough 460 adjoins the second portion and forms an electrically conducting contact surface 463. This is adjoined by connections 476 of a capacitor unit 475, which is configured as an SMD component. The capacitor unit 475 has connections 476 and 477 of its own in the form of connection areas. By way of these, it is connected to the remaining filter structure. The connection 477 of the capacitor unit 475 is connected to a third portion 471" by way of a further contact surface 491 of a connection element 465. The connection element 465 is provided by the same material as the leadthrough 460 and is embedded in the main filter structure body. The connecting portion 471" may be connected to the connecting portions 471' and 471 or may be provided as one part with them. The connecting portion 471" is formed on a circumferential outer side of the main filter structure body as a metallization layer. The capacitor unit 475 is a physically independent, frequency-selective component in the form of a capacitor that is connected to the remaining filter structure by way of connections of its own. The capacitor unit 475 is partially or completely recessed in a depression on an outer side of the main filter structure body. A protective layer 495 covers the capacitor unit 475 and closes off the depression.

[0162] In FIGS. 1-5, reference numerals with the same last two digits concern comparable components that correspond in their properties and functions.

[0163] FIG. 5 illustrates that capacitors and inductors may be provided in each case as independent components or as components integrated in the main filter structure body. The first and second capacitors 470, 470', 472 and 473 together form a first parallel capacitor. The inductor 474 forms a series inductor. The capacitor 475 forms a second parallel capacitor. This produces along the leadthrough 460 a π filter (pi filter), which operates as a low-pass filter and conducts RF components by way of the connecting portions to ground or to the housing. The connecting portions may be electrically connected to the conducting securing element.

[0164] FIG. 5, for example, illustrates that the filter structure and the feedthrough are independent bodies that are connected to one another by way of a surface connection (per conducting element or per leadthrough). The connection can be represented very easily, for example, if the distance between the first surface contact and the associated second surface contact for each surface contact is the same. The connection can be established by customary automatic placement machines for SMD technology. This allows a high degree of efficiency and precision, while it is possible to rely on already established technology. Instead of a soldered connection, plug-in or press-on contacts may also be provided as the surface connection, or else electrically conducting adhesively bonded connections (for instance anisotropic adhesively bonded connections).
20. The contacting arrangement of claim 16, the filter structure having at least one electrically conducting surface, and the electrically conducting surface also forming an electrode surface of a capacitor or the electrically conducting surface forming a contact surface to which a frequency-selective component of the filter structure is connected, or the filter structure having at least one conducting portion in particular a leadthrough of the filter structure, and the conducting portion being provided by an inductor of the filter structure.

21. The contacting arrangement of claim 20, the electrode surface of the capacitor or the conducting portion of the inductor being provided by a conducting material that is integrated in an electrically insulating main filter structure body of the filter structure, or the frequency-selective component being formed as a physically independent component that has connection areas or connection pins of its own, which are electrically connected to the contact area by way of a soldered connection or by way of a press-fit connection.

22. The contacting arrangement of claim 20, the electrically conducting surface forming an electrode surface of a capacitor and the electrode surface being provided by a conducting material, a sintered metal or a cermet, and the capacitor also having a dielectric layer that is formed by a portion of the electrically insulating main filter structure body, the dielectric layer preferably comprising a dielectric with a relative permittivity of more than 20, or a ferroelectric or a paraelectric.

23. The contacting arrangement of claim 20, the electrically conducting surfaces being provided multiply in the filter structure, forming multiple electrode surfaces of a capacitor, the multiple electrode surfaces running parallel to one another and a first group of the electrode surfaces being connected to one another in an electrically conducting manner, and a second group of the electrode surfaces being connected to one another in an electrically conducting manner in order to provide the capacitor as a multilayer capacitor unit.

24. The contacting arrangement of claim 20, the filter structure being directly adjacent to the feedthrough by way of the surface connection and being electrically connected to it at one or more different points.

25. A medically implantable device comprising: a contacting arrangement configured within a housing of the medically implantable device; the contacting arrangement comprising an electrical feedthrough that has at least one electrically insulating main feedthrough body and at least one electrically conducting element; the conducting element configured to establish at least one electrically conducting connection between an interior of the housing and an exterior through the main feedthrough body; the conducting element being hermetically sealed with respect to the main feedthrough body; and

the at least one conducting element comprising at least one cermet; characterized in that the contacting arrangement also comprises an electrical filter structure that is arranged on an end face of the feedthrough and is connected to the conducting element by way of at least one electrical surface connection.

26. The medically implantable device of claim 25, wherein the electrical feedthrough is configured in the housing with a holding element that surrounds the electrical feedthrough, and the filter structure extends away from the electrical feedthrough and protrudes at least partially into the interior.

27. A method for producing a contacting arrangement for a medically implantable device, the method comprising: a) creating a green feedthrough blank with a structure of an electrically insulating material to form a main feedthrough body and a structure of a metal- or cermet-containing material to form at least one conducting element within the main feedthrough body; b) firing the green feedthrough blank; c) creating a green filter structure blank with a structure of an electrically insulating material to form a main filter structure body and a structure of a metal- or cermet-containing material to form at least one electrically conducting surface, a conducting portion and/or a leadthrough within the main filter structure body; d) firing the green filter structure blank; and e) arranging the filter structure on an end face of the feedthrough and establishing at least one electrical surface connection between the filter structure and the feedthrough.

28. The method of claim 27, wherein the at least one electrical surface connection is established by a surface soldering process or by adhesive bonding, using an electrically conductive adhesive, or by a welding process.

29. The method of claim 27, wherein the green filter structure blank is created by preparing a suspension that contains at least one dielectric, and in particular a paraelectric or ferroelectric material, forming the suspension into at least one body and printing the at least one body with a paste that contains electrically conductive material, the method also providing firing of the printed body in order to create the filter structure.

30. The method of claim 29, wherein the suspension is formed in multiple layers, which form the at least one body, the layers in each case being printed with the paste in areas that are offset alternately in relation to one another, and the printed layers being pressed before they are cut up into a multiplicity of filter structures, and furthermore, before the firing, a binder contained in the suspension being removed.

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