

[54] **PERCUTANEOUS MYO-ELECTRODE SYSTEM**

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[58] Field of Search3/1, 1.1; 128/DIG. 4, 2.1 E, 128/2.06 E, 404, 418, 419 P

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[57] **ABSTRACT**

A percutaneous myo-electrode system for facilitating either the stimulation of, or the extraction of electrical energy due to, muscular activity within the body of a vertebrate. A percutaneous member of a biocompatible carbon material is insertable into an aperture in the body tissue such that a surface thereof is substantially flush with the outer skin of the body tissue. At least one connecting member of electrically conductive biocompatible material is secured within and electrically insulated from the percutaneous member. One end of the, or each, connecting member is connectable, at the surface of the body tissue, to an electrical energy source or user external of the body, whilst the other end thereof is connected to an electrode of an electrically conductive biocompatible material by means of a connecting lead of an electrically conductive biocompatible material. The electrode is connectable to a muscle within the body. The electrical energy user can be an artificial limb, and the external electrical energy source can be used to stimulate the heart of the vertebrate.

9 Claims, 2 Drawing Figures

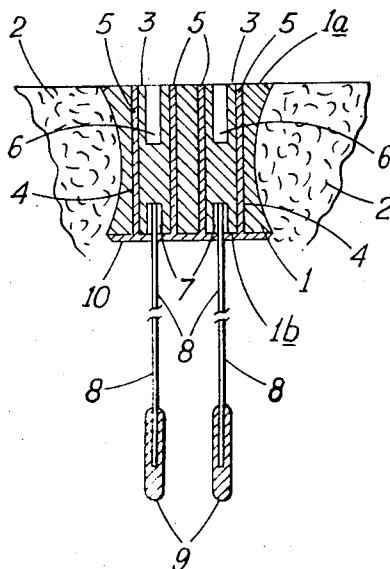


Fig. 1.

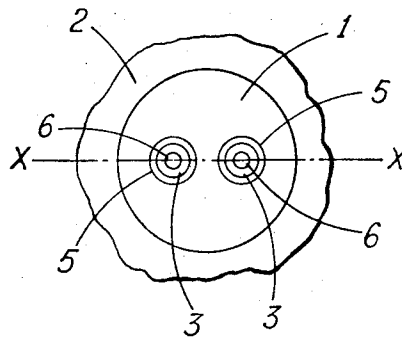
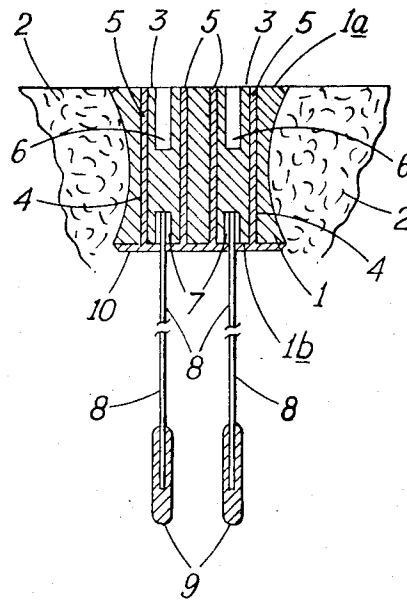


Fig. 2.



PERCUTANEOUS MYO-ELECTRODE SYSTEM

The invention relates to a percutaneous myo-electrode system for facilitating the stimulation of, or the extraction of electrical energy due to, muscular activity within the body of a vertebrate.

It is known that carbon materials which are microcrystalline in structure, and substantially impermeable, for example those known as vitreous, glassy or pyrolytic carbons, are chemically, biologically and physically compatible with animal tissue and electrically conductive. These materials are, therefore, ideally suited for use as a percutaneous myo-electrode system material.

The invention provides a percutaneous myo-electrode system for facilitating the stimulation of, or the extraction of electrical energy due to, muscular activity within the body of a vertebrate, including a percutaneous member of carbon material which is electrically conductive, microcrystalline in structure and substantially impermeable, the percutaneous member being insertable into an aperture in the body tissue such that a surface thereof is substantially flush with the outer skin of the body tissue; a connecting member of the said carbon material which is secured within and electrically insulated from the percutaneous member, one end of the connecting member being connectable, at the said surface of the percutaneous member, to an electrical energy source or user external of the said body; an electrode of an electrically conductive biocompatible material which is connectable to a muscle within the said body; and a connecting lead of an electrically conductive biocompatible material which is secured at one end in electrical contact with the other end of the connecting member, and at the other end in electrical contact with the electrode.

The electrical energy user external of the said body can be an electrical indicating or recording apparatus or an electrically actuatable mechanism which can form part of an artificial limb. The external electrical energy source is used to stimulate a body muscle, for example the heart of the vertebrate.

In order to improve the retention of the percutaneous myo-electrode system within the body tissue, the surface of the percutaneous member in contact with the body tissue can be roughened to assist the keying in of the member by a fibrous interfacial layer.

The foregoing and other features according to the invention will be better understood from the following description with reference to the accompanying drawings, in which:

FIG. 1 diagrammatically illustrates a plan view of a percutaneous myo-electrode system according to the invention, and

FIG. 2 diagrammatically illustrates a cross-sectional side elevation of the percutaneous myo-electrode system according to FIG. 1 on the line 'X—X.'

Referring to the drawings, a percutaneous myo-electrode system according to the invention is diagrammatically illustrated therein implanted in the body tissue of a vertebrate. The myo-electrode system includes a percutaneous member 1 implanted in the body tissue 2 of the vertebrate, such that the surface 1a is substantially flush with the outer skin of the body tissue 2. The percutaneous member 1 is formed from a carbon material, for example vitreous carbon, which is electri-

cally conductive, microcrystalline in structure, and substantially impermeable, and which, as stated in a preceding paragraph, is compatible with animal tissue and, therefore, ideally suited for this purpose. Furthermore, the utilization of a percutaneous implant of this type of material results in the formation of a germ-free entry to the body of the vertebrate which, it is thought, is due in the main to the formation of a protective epithelial downgrowth of fibrous material at the interface between the body tissue 2 and the carbon percutaneous member 1.

Two connecting members 3 of a carbon material of the kind outlined in the preceding paragraph, for example vitreous carbon, are each secured within an aperture 4 in the member 1 and electrically insulated from the member 1 and thereby from each other by an annular layer 5 of a biocompatible electrically insulating material.

Each of the connecting members 3 is provided at one end with an aperture 6. The apertures 6 which form a two-pin plug socket, are arranged to receive a two-pin plug from a co-operating connector (not illustrated). An aperture 7 is provided in the other end of each of the connecting members 3 into which is secured in electrical contact therewith one end of an electrically conductive lead 8. The leads 8 are of a biocompatible electrically conductive material.

The other end of each of the leads 8 is secured to an electrode 9 of a biocompatible material which is insertable into, or connectable to, a muscle of the body of the vertebrate.

The surface 1b of the percutaneous member 1 can be provided with a layer 10 of a biocompatible electrically insulating material when the electrical conductivity of the body tissue 2 and/or the body fluids is such that electrical conduction therein between the connecting members 3 or between the members 3 and the percutaneous member 1 affects the operation of the equipment associated with the percutaneous myo-electrode system.

The members 1 and 3 when of a solid vitreous or glassy carbon, are formed by the thermal degradation of organic materials. One process for producing impermeable carbon bodies is described in U.S. Pat. specification No. 3,109,712 and British Pat. specification No. 956,452. In bulk form, vitreous carbons have a density of approximately 1.5 and exhibit a conchoidal fracture and are nonporous.

When the members 1 and 3 are of a solid pyrolytic carbon, they are formed by carbonizing simple organic compounds, for example as described in one of the abovementioned Patent specifications.

A suitable biocompatible electrically conductive material for each of the electrically conductive leads 8 is a carbon fiber filament. The carbon fiber filament would be sealed at one end into the aperture 7 and at the other end into the electrode 9. The electrode 9 can be of a carbon material of the kind outlined in a preceding paragraph, for example vitreous carbon. The sealing of the carbon fiber filament into the aperture 7 and the electrode 9 can, when the members 3 and the electrode 9 are of vitreous carbon, be effected with a phenolic resin such as phenol-formaldehyde which is a precursor of vitreous carbon and electrically insulating when in moulding powder or casting resin form. In

order to convert the electrically insulating phenolic resin into an electrically conductive material it is necessary to cure it at a temperature of the order of 1,800°C in a nitrogen atmosphere.

The biocompatible electrically insulating layers 5 and 10 can also be of a phenolic resin such as phenol-formaldehyde which should be cured at a temperature of the order of 400°C in order that its electrically insulating properties are retained. Other biocompatible electrically insulating materials can be utilized, for example a layer of a carbide forming element such as silicon can be deposited on the cylindrical surface of the connecting members 3 which will form a seal with the connecting members 3. When the members 3 are inserted into the apertures 4 and heated to a temperature of the order of 1,200°C to 1,300°C, the deposited silicon melts and reacts with the carbon content of the members 1 and 3 to form annular layers 5 of silicon carbide. The layer 10, when provided, can also be of silicon carbide and produced in this manner.

In some instances it may be advantageous for the surface or surfaces of the percutaneous member 1 in contact with the body tissue 2 to be roughened in order to assist the keying in of the member 1 by the previously mentioned epithelial downgrowth of fibrous material which forms between the body tissue and the carbon percutaneous member 1. This roughness may be achieved by machining the surface, preferably before firing, or by first coating the surface with granules of phenolic resin, or fibers of carbon, or a suitable polymer before carbonizing.

In operation, the electrodes 9 would be implanted into, or attached to a muscle which is to be stimulated or whose electrical impulse are to be transferred to utilization means external of the body tissue 2, and the percutaneous member 1 and associated parts would be implanted in the body tissue. Thus, by fitting a two-pin plug from a co-operating connector of an external apparatus into the apertures 6 of the connecting members 3, electrical currents generated by the muscular activity of the muscle or muscles to which the electrodes 9 are connected can be either measured, or recorded, or utilized to actuate a mechanism or mechanisms associated with the operation of an artificial limb.

Alternatively, the electrodes could be connected via the two-pin plug to an external source of electrical power and utilized to pass electrical currents into a body muscle in order to stimulate it.

It should of course be noted that whilst a percutaneous myo-electrode system has been described and illustrated with a two-pin plug socket, the invention should not be considered as being limited to this arrangement since a one-pin or a multi-pin plug socket are within the scope of the invention. These arrangements are realized merely by providing the requisite number of connecting members 3 and associated electrodes 9 and connecting leads 8, and a percutaneous member 1 of sufficient proportions to house the connecting members 3.

It is to be understood that the foregoing description of specific examples of this invention is made by way of

example only and is not to be considered as a limitation in its scope. What is claimed is:

1. A percutaneous myo-electrode system for facilitating the simulation of, or the extraction of electrical energy due to, muscular activity within the body of a vertebrate, including a percutaneous member of carbon material which is electrically conductive, microcrystalline in structure and substantially impermeable, the percutaneous member being insertable into an aperture in the body tissue such that a surface thereof is substantially flush with the outer skin of the body tissue; a connecting member of the said carbon material which is secured within and electrically insulated from the percutaneous member, one end of the connecting member being connectable, at the said surface of the percutaneous member, to an electrical energy source or user external of the said body; an electrode of an electrically conductive biocompatible material which is connectable to a muscle within the said body; and a connecting lead of an electrically conductive biocompatible material which is secured at one end in electrical contact with the other end of the connecting member, and at the other end in electrical contact with the electrode.

2. A percutaneous myo-electrode system as claimed in claim 1 which includes at least two of the connecting members each one of which is connected to an electrode by a connecting lead.

3. A percutaneous myo-electrode system as claimed in claim 2 which includes a layer of a biocompatible electrically insulating material formed on a surface of the percutaneous member such that it effects electrical isolation between the said other ends of each of the connecting members.

4. A percutaneous myo-electrode system as claimed in claim 1 wherein a surface of the percutaneous member for engagement with the aperture in the body is roughened.

5. A percutaneous myo-electrode system as claimed in claim 1 wherein said connecting member is electrically insulated from the percutaneous member by a layer of a biocompatible electrically insulating material interposed between the connecting member and the percutaneous member.

6. A percutaneous myo-electrode system as claimed in claim 3 wherein the said layer is of a material taken from the group consisting of silicon carbide, and electrically insulating phenolic resin.

7. A percutaneous myo-electrode system as claimed in claim 1 wherein the carbon material is taken from the group consisting of vitreous carbon, glassy carbon, and pyrolytic carbon.

8. A percutaneous myo-electrode system as claimed in claim 1 wherein said electrode is of a material taken from the group consisting of vitreous carbon, glassy carbon, and pyrolytic carbon.

9. A percutaneous myo-electrode system as claimed in claim 1 wherein the electrically conductive biocompatible material of said connecting lead is a carbon fiber filament.

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