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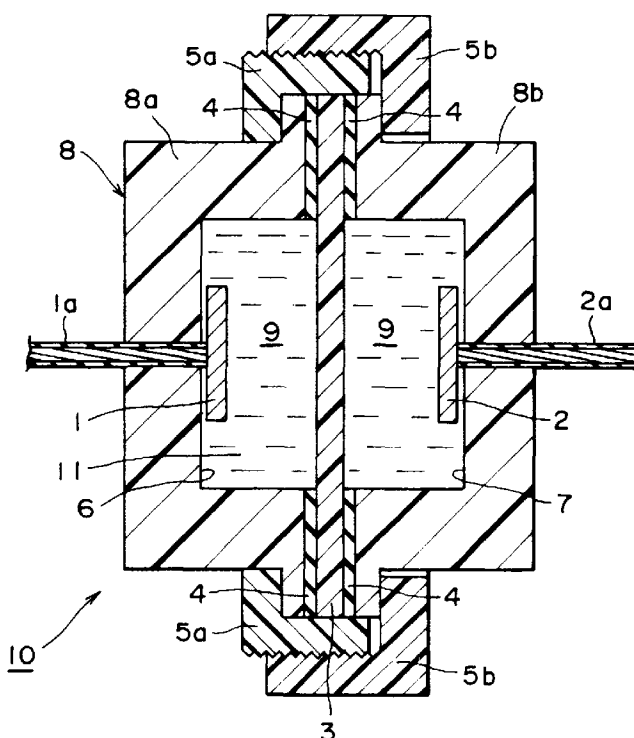
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(54) Non-linear resistor using poly (amino acid) membrane

(57) A nonlinear resistor is disclosed which includes a housing in which a membrane of a water-insoluble poly(amino acid) having ionic side chains is disposed to divide the space within the housing into first and second chambers. An electrolyte-containing hydrogel is con-

tained in each of the first and second chambers for electrical contact with the membrane. First and second electrodes are disposed in the first and second chambers, respectively, for electrical contact with the corresponding hydrogel and are coupled with first and second lead wires, respectively, each extending out of the housing.

F I G. 1



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Description

Background of the Invention

This invention relates to an improved nonlinear resistor using a poly(amino acid) membrane.

JP-A-Hei-1-278701 (Minoura et al) suggests a nonlinear resistor including a housing defining a space therewithin; a membrane disposed within the space to divide the space into first and second chambers and formed of a water-insoluble poly(amino acid) having ionic side chains; an aqueous salt solution contained in each of the first and second chambers for electrical contact with the membrane; and first and second electrodes disposed in the first and second chambers, respectively, for electrical contact with the corresponding aqueous salt solution. Because of the use of the aqueous salt solution, the known nonlinear resistor poses a problem in handling, storage and transportation. Further, air bubbles are apt to deposit on the electrode surfaces during use, causing changes of the resistor characteristics.

Summary of the Invention

The present invention provides a nonlinear resistor, which includes:

a housing defining a space therewithin;
a membrane disposed within the space to divide the space into first and second chambers, the membrane being formed of a water-insoluble poly(amino acid) having ionic side chains;
an electrolyte-containing hydrogel contained in each of the first and second chambers for electrical contact with the membrane;
first and second electrodes disposed in the first and second chambers, respectively, for electrical contact with the corresponding hydrogel; and
first and second lead wires coupled with the first and second electrodes, respectively, and each extending out of the housing.

The use of a hydrogel can solve the problem of the known linear resistor using an aqueous salt solution.

It is, therefore, an object of the present invention to provide a nonlinear resistor which is free of problems during its handling, storage and transportation.

Brief Description of the Drawings

Other objects, features and advantages of the present invention will become apparent from the detailed description of the preferred embodiments of the invention which follows, when considered in light of the accompanying drawings, in which:

Fig. 1 is a vertical, cross-sectional view diagrammatically showing one embodiment of a nonlinear

resistor according to the present invention; and Fig. 2 is nonlinear current-voltage characteristics of a resistor obtained in the working example.

Detailed Description of the Preferred

Embodiments of the Invention

Referring now to Fig. 1, designated generally as 10 is a nonlinear resistor according to the present invention. The resistor 10 includes a cylindrical housing 8 defining a space 11 therewithin and made of an electrical insulator such as a plastic. Disposed, perpendicularly to the axis of the cylindrical housing 8, in the space 11 is a circular membrane 3 for dividing the space 11 into first and second chambers 6 and 7, respectively. The membrane 3 is formed of a water-insoluble poly(amino acid) having ionic side chains. An electrolyte-containing hydrogel 9 is contained in each of the first and second chambers 6 and 7 for direct contact with the membrane 3. Designated as 1 and 2 are first and second electrodes disposed in the first and second chambers 6 and 7, respectively, for electrical contact with the corresponding hydrogel 9. The first and second electrodes 1 and 2 are coupled with first and second lead wires 1a and 2a, respectively, each extending out of the housing 8. The reference numeral 4 designates an annular packing for sealing the interface between the membrane 3 and the housing 8.

In the illustrated embodiment, the housing 8 is composed of a pair of flanged vessels 8a and 8b which are tightly connected together by means of a suitable joint such as cap nuts 5a and 5b which are threading engagement with each other.

Typical examples of the ionic side chains of the water-insoluble poly(amino acid) includes $-\text{COOH}$ and $-\text{NH}_2$. Thus, the water-insoluble poly(amino acid) may be obtained from, for example, glutamic acid, aspartic acid, lysine or ornithine. Since a poly(amino acid) obtained only from these amino acid monomers is soluble in water, a hydrophobic group-containing amino acid such as leucine, alanine or methionine is used in conjunction with the ionic group-containing amino acid to form a water-insoluble random or block copolymer. Such a copolymer is molded into a membrane by any known method. The membrane preferably has a thickness of 1-100 μm .

The electrolyte-containing hydrogel phase 9 contained in the chambers 6 and 7 may be obtained by dissolving the electrolyte in water. A gelling agent is then added into the aqueous electrolyte solution to form the hydrogel. The electrolyte may be an organic or inorganic acid salt such as an alkali metal chloride, an alkaline earth metal chloride or an alkali metal acetate. The aqueous electrolyte solution preferably has an electrolyte content of 0.0001 to 4 moles per liter. The gelling agent may be, for example, a polysaccharide having no dissociation groups, e.g. agarose, starch or cellulose;

or a water-soluble synthetic polymer, e.g. polyacrylamide, polyvinyl alcohol, polyethylene glycol or poly(hydroxyethylmethacrylate). The gelling agent is generally used in an amount of 1-10 parts by weight, preferably 2-5 parts by weight, per 100 parts by weight of the aqueous electrolyte solution.

The electrodes 1 and 2 may be, for example, Ag covered with AgCl.

The following examples will further illustrate the present invention.

Example 1

A water-insoluble poly(amino acid) film (thickness: 20 pm) formed of a block copolymer having a structure of $(\text{Glu})_m-(\text{Leu})_p-(\text{Glu})_n$ (total Glu content: 36 mole %; m, p and n show the degree of polymerization) was prepared by first polymerizing L-leucine-N-carboxylic anhydride using 1,6-hexamethylene diamine as a polymerization initiator in a mixed solvent of benzene/dioxane (19/1 weight ratio) at room temperature. To the reaction mixture was then added γ -benzyl glutamate N-carboxylic anhydride to form a benzyl glutamate-leucine-benzyl glutamate triblock copolymer. The copolymer was dissolved in benzene and the solution was evenly applied onto a glass plate. The coating was then dried to leave a film of the triblock copolymer having a thickness of 0.02 mm. The film was then treated with 5 N sodium hydroxide in a water-isopropanol-methanol solvent to hydrolyze the benzyl ester groups, thereby obtaining the Glu-Leu-Glu copolymer film 3. The copolymer film was immersed in an aqueous KCl solution having a KCl concentration of 10 mmol/liter for 30 minutes. The both sides of the film 3 were then wiped with a filter paper.

Agarose (0.5 g) was dissolved in an aqueous KCl solution (20 ml) having a KCl concentration of 10 mmol/liter with heating at about 80°C. The warm solution was then poured in each of two poly(vinyl chloride) resin vessels 8a and 8b (Fig. 1) and cooled to room temperature to form a hydrogel 9. Each of the vessels 8a and 8b was provided with an Ag/AgCl electrode 1 or 2 coupled with a lead wire 1a or 2a and had an inside volume of 0.5 ml.

The hydrogel-containing vessels 8a and 8b were connected face to face with the copolymer film 3 being interposed therebetween, thereby obtaining a resistor 10.

Fig. 2 shows current/voltage characteristics of the thus obtained resistor with a sweep rate of 40 $\mu\text{A}/\text{sec}$. As seen in Fig. 2, the resistance depends upon the electrical current and a hysteresis is observed.

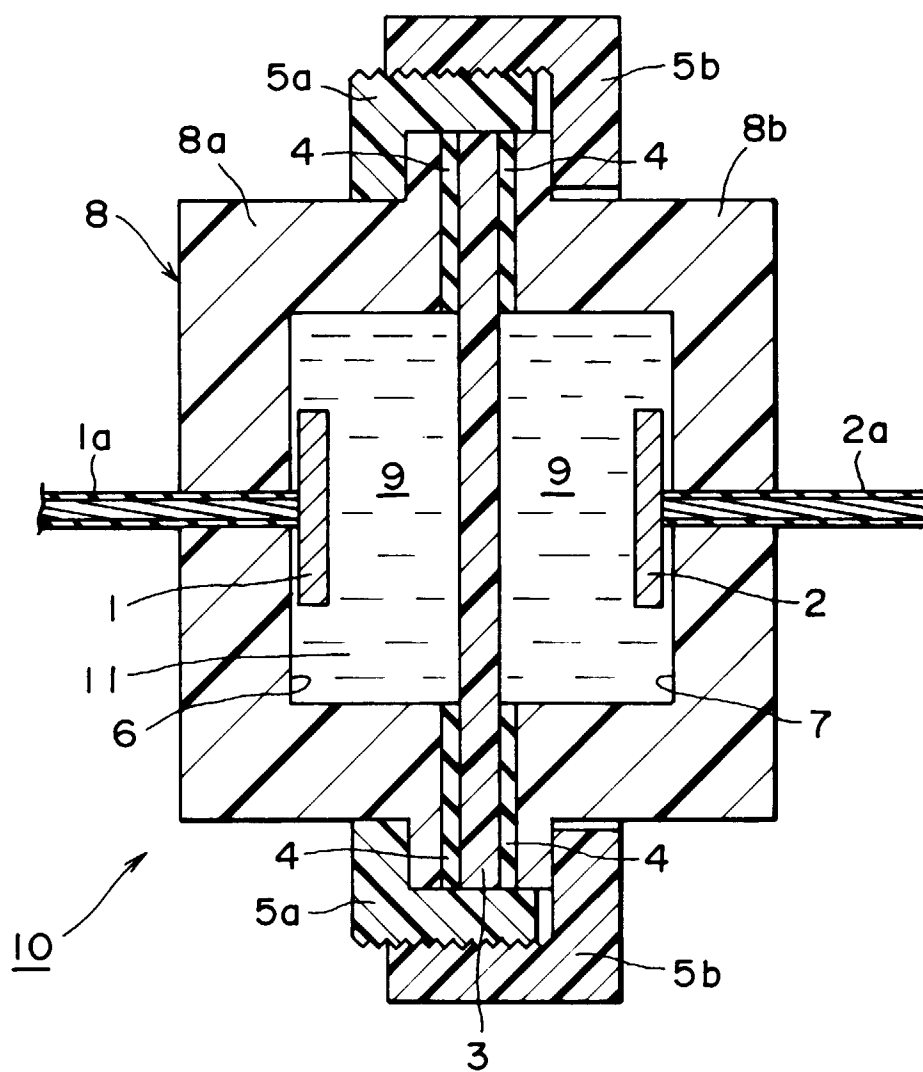
The invention may be embodied in other specific forms without departing from the spirit or essential characteristics thereof. The present embodiments are therefore to be considered in all respects as illustrative and not restrictive, the scope of the invention being indicated by the appended claims rather than by the foregoing description, and all the changes which come within the meaning and range of equivalency of the claims are

therefore intended to be embraced therein.

Claims

1. A nonlinear resistor comprising:
 - a housing defining a space therewithin;
 - a membrane disposed within said space to divide said space into first and second chambers, said membrane being formed of a water-insoluble poly(amino acid) having ionic side chains;
 - an electrolyte-containing hydrogel contained in each of said first and second chambers for electrical contact with said membrane;
 - first and second electrodes disposed in said first and second chambers, respectively, for electrical contact with the corresponding hydrogel; and
 - first and second lead wires coupled with said first and second electrodes, respectively and each extending out of said housing.
2. A nonlinear resistor as claimed in claim 1, wherein said water-insoluble poly(amino acid) comprises a first monomeric unit selected from the group consisting of glutamic acid, aspartic acid, lysine and ornithine, and a second monomeric unit selected from the group consisting of leucine, alanine and methionine.
3. A nonlinear resistor as claimed in claim 1, wherein said hydrogel is formed of agarose or polyacrylamide.
4. A nonlinear resistor as claimed in claim 1, wherein said electrolyte is a salt selected from the group consisting of alkali metal chlorides, alkaline earth metal chlorides and alkali metal acetates.
5. A nonlinear resistor as claimed in claim 1, the concentration of said electrolyte in said hydrogel is 0.0001 to 4 moles per liter.
6. A linear resistor as claimed in claim 1, wherein said membrane has a thickness of 1-100 μm .

FIG. 1



F I G . 2

