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F. P. BURNS

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PIEZORESISTIVE SEMICONDUCTOR MICROPHONE

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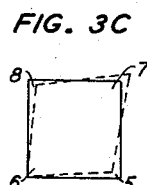
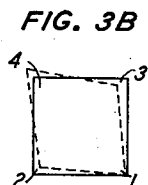
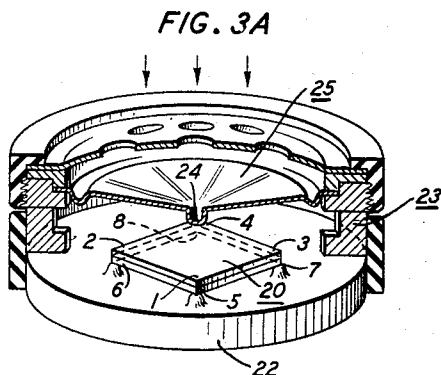
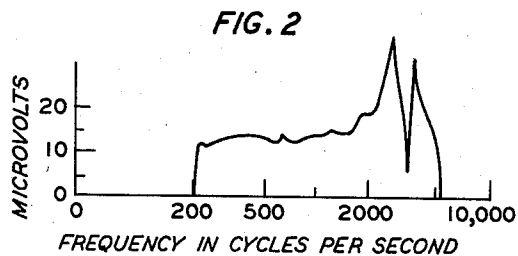
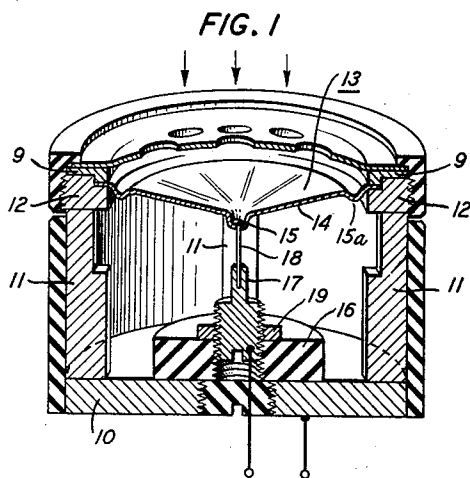


FIG. 3D

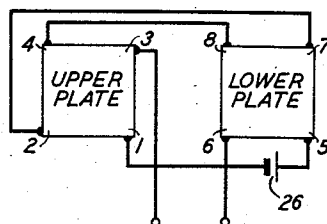


FIG. 3F

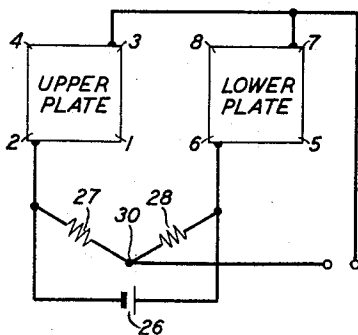
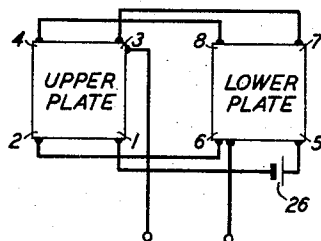


FIG. 3E



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PIEZORESISTIVE SEMICONDUCTOR MICROPHONE

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8 Claims. (Cl. 179-110)

This invention relates in general to acoustical translation devices and more particularly to a microphone which utilizes the piezoresistive property of a semiconductor material.

The well known current-biased carbon granule microphone has for many years been a major component of a standard telephone system. The early choice of this unit, and the subsequent standardization of telephone systems to include it, were well justified on the ground of its high power capacity, and its high efficiency at high signal levels. In particular, the conventional carbon granule microphone is capable of accepting the high acoustic power of the voice of an abnormally loud talker, and of delivering a corresponding electrical signal without excessive overload. Furthermore the instrument is characterized by a very high efficiency under such a high power condition. But, like any instrumentality constructed to translate a large amount of power, its operating efficiency is inevitably low when the power it translates is low, as in the case of accepting a subdued or whispered sound and translating it into a corresponding electrical signal.

With the advent of rugged, reliable amplifiers of high efficiency, and especially of transistor amplifiers which occupy only an inconsequential volume, the need for delivery by the microphone of electrical signals at high power levels is greatly reduced. Consequently the combination of a microphone of low efficiency with such a high efficiency amplifier can compete with the carbon granule microphone and, indeed, offers substantial advantages, as compared with the carbon granule microphone, in the way of overall efficiency, reduction of required bias current and the like, provided only that the microphone itself can accept speech delivered at high acoustic power levels. It is with such a microphone, to be employed preferably in conjunction with a transistor amplifier, that the present invention deals.

A new type of microphone, which in association with a suitable amplifier, provides a possible alternative to the carbon granule microphone conventionally used in telephone systems, relies for its operation on a recently discovered piezoresistive characteristic of semiconductor materials. Several types of piezoresistive microphones employing germanium and silicon as the piezoresistive materials are disclosed in F. P. Burns application Serial No. 543,860, filed October 31, 1955 now Patent No. 2,866,014, granted December 23, 1958. However, in each of these materials the piezoresistive characteristic is an isotropic, necessitating a specific crystal orientation of the active element for optimum effectiveness. Moreover, since germanium and silicon have high resistivities, they are unsuitable in certain types of circuit arrangements for matching with low impedances, such as might be desirable in working into transistor amplification.

Accordingly, it is the general object of the present invention to provide substantial improvements in the design and construction of piezoresistive microphones.

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A more particular object of the invention is to provide a microphone which comprises a material having an isotropic piezoresistive characteristic, and which, accordingly, does not require specific crystallographic orientation.

Another object of the invention is to provide a microphone which is adapted for impedance matching to transistor amplification.

These and other objects are realized in piezoresistive microphone structures in accordance with the present invention including as their active material indium antimonide, which is characterized by an isotropic piezoresistive characteristic, and a relatively low resistivity as compared with germanium and silicon. The present invention contemplates several different embodiments.

One form comprises a rod microphone including a diaphragm of a type presently used in telephone microphones, the center button of which is attached to a rod of indium antimonide maintained under axial tension, and varies this axial tension so as to change the resistance of the rod and, hence, the current through a circuit of which it is a part. A particular feature of this design is that the resistance of the indium antimonide element is such that it substantially matches the input impedance of a transistor amplifier.

In accordance with another embodiment of the invention, a bimorph element comprising a pair of substantially rectangular plates in matched face-to-face relation, with an insulating material sandwiched between, is disposed with the three lower corners rigidly attached to a frame, and the fourth corner subject to deformation in response to the movement of a diaphragm, which produces shearing action in the plates, the latter being translated into a substantial voltage variation in the output circuit.

Other objects, features and advantages of the present invention will be apparent to those skilled in the art after a study of the specification hereinafter with reference to the attached drawings, in which:

Fig. 1 shows a rod microphone, in accordance with the present invention, including indium antimonide as the active element;

Fig. 2 is a plot of output in microvolts versus frequency in cycles per second for the microphone of Fig. 1 over the audio range;

Fig. 3A shows a modified microphone embodiment of the present invention, in which shear deformation produces a marked piezoresistive response in the element;

Figs. 3B and 3C are diagrams illustrating the mechanical deformation which occurs in the bimorph element of Fig. 3A; and

Figs. 3D, 3E and 3F illustrate three alternative electrical circuit connections for the bimorph element of Fig. 3A.

In accordance with one embodiment of the invention, shown in cross section in Fig. 1 of the drawings, the microphone structure consists of a thin metallic diaphragm 13 having its outer periphery rigidly clamped to the upper surface of a cylindrical framework. A thin semiconductor rod 18, more specifically of indium antimonide, is rigidly connected, under tension, between a contact button at the center of the inner surface of the diaphragm 13 and an insulated metallic mounting 17 which projects upwardly from the base 10 of the framework.

The frame is made of lightweight metal, such as aluminum. It may consist, for example, of a base plate 10 about 5 centimeters in diameter and a few millimeters thick upon which are symmetrically mounted four supporting posts 11, machined flush with the outer edge of the plate. Seated on the flat upper surfaces of the four

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supporting posts 11, at a separation of about 3 centimeters from the base plate 10, is an annular member 12, the outer diameter of which coincides with that of the base plate 10, and the inner diameter of which is about 8 millimeters less than the outer diameter. The annular member 12 is flanged around the upper inner edge to provide a seating for the peripheral flange on the diaphragm 13. This is held in place by another flanged annular fitting 9. The outer surface of diaphragm 13 may be protected, for example, by a perforated, hard rubber plate, of a form well known, which rests on the annular fitting 9. The entire microphone assemblage may be encased, for protection, in a hard rubber housing.

The diaphragm 13, which is of the general form indicated, for example, in Fig. 1 of H. W. Bryant Patent 2,532,694, granted December 5, 1950, preferably consists of lightweight metal, such as aluminum. It comprises a shallow, inwardly directed, frusto-conical portion 14, provided with an annular, downwardly directed corrugation 15a adjacent the peripheral flanged portion, and also a number of radially directed stiffening corrugations. Fixed to the center of the inner surface of the frusto-conical portion 14 of the diaphragm 13 is a hemispherical, gold contact button 15 which measures about a half centimeter across the base.

A metallic shaft 17 projects upwardly from a hole in the center of an insulating disk 16 which is fixed to the upper surface of the base plate 10. The lower cylindrical portion of the shaft 17 is screw-threaded, and the flat lower end is recessed to receive a screw fitting, which is insulated from the base plate 10, and is arranged to provide contact to an external circuit through an insulated passage in the base plate 10. A nut 19, which rests on the upper surface of the insulating disk 16, screws onto the shaft 17, and holds it rigidly in position. The upper, narrow portion of the shaft 17 is about 2 millimeters long and 2 millimeters in diameter, whereas the screw-threaded portion which engages the nut and the including disk 16 has a diameter of about a half centimeter.

The center of the gold button 15 and the top of shaft 17 each contain a small hole dimensioned to hold fast the ends of a thin rod 18 of semiconductor material about 1 centimeter long, and with a cross-sectional area of about 10^{-4} square centimeters.

A specific technique for preparing a single crystal indium antimonide rod of suitable cross-sectional dimension for the purposes of the present invention is carried out as follows.

Ingots of polycrystalline indium antimonide having an impurity carrier concentration of not greater than 10^{16} per cubic centimeter can be obtained commercially from the Ohio Semiconductor Company, Columbus, Ohio. These are melted down and formed into single crystals by a method well known in the art, which comprises pulling a seed crystal from a melt in the manner similar to that used in the preparation of germanium single crystals, and which is described, for example, by G. K. Teal and J. B. Little in the Physical Review, vol 78, page 647, 1950.

The single crystals so formed are sliced into wafers about $1\frac{1}{2}$ centimeters on a side, and about $\frac{1}{2}$ millimeter thick. A series of fine parallel saw cuts about $\frac{1}{2}$ millimeter apart are made in the wafer, after which the wafer is turned over, and the side with the cuts fastened to a block with wax. The exposed side is lapped down to the saw cuts by techniques well known in the art, thus leaving a row of parallel rods which can be made with a cross-sectional area as small as 75 microns square. Even smaller cross sections are obtainable by carefully controlled etching, which is carried out slowly enough to preserve the rectangular form of the cross section. An etchant which has been found suitable for the process under description consists of equal parts of nitric acid, hydrofluoric acid, and a 1 percent aqueous solution of silver nitrate.

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After an indium antimonide rod 18 has been cut, lapped and etched to the desired dimensions, in the manner indicated in the foregoing paragraphs, it is mounted in the following manner in the holes provided in the gold button 15 and the protruding shaft 17.

Contact is made to the rod 18 with indium alloy solder, the ends of the rod 18 and the centrally located holes in the shaft 17 and the gold button 15 having first been tinned. When the rod 18 is in place, extra solder is added, and the contacts are heated with a soldering iron. The solder at the gold button contact 15 is heated last, while the diaphragm 13 is distended by means of a weight corresponding to the desired amount of the tensile bias, the magnitude of the weight to be computed in a manner which will be described in greater detail hereinafter. The purpose of the tensile bias imposed on the rod 18 is to prevent buckling and impact loading during operation of the microphone, and also to prevent second harmonic distortion. Usually, the contact area extends over about .15 centimeter of the length of the rod at each end, leaving a length of about 1 centimeter extending between the contacts. Ohmic contacts are provided by an indium alloy solder, which consists of 25 percent indium, together with tin and lead. Although unalloyed indium solder can be used for this purpose, the alloy solder is harder and is less likely to relax the tensile bias.

Inasmuch as the piezoresistive characteristic of the indium antimonide is isotropic, the microphone rods of this material do not have to be oriented in any specific crystalline direction for optimum performance. Moreover, because of this isotropic characteristic, polycrystalline rods, as well as single crystalline rods of indium antimonide, can be used for the purposes of the present invention, thereby eliminating at least one costly and time-consuming step in the preparation, which involves the process of preparing single crystals.

If germanium or silicon rods are used for the purposes of the present invention, they are prepared in single crystalline form, and are oriented, in each case, for the direction of maximum piezoresistive effect, which is in the [111] crystallographic direction for both P and N type germanium, and for P type silicon, and in the [100] direction for N type silicon. Accordingly, in embodiments involving these materials, the rod 18 is oriented with the long axis in the direction of maximum piezoresistive effect.

In order to provide a design in accordance with Fig. 1 of the drawings, which gives optimum performance, it is necessary to take into account certain theoretical considerations.

The design of a piezoresistive transducer is influenced primarily by impedance matching considerations. The stiffness associated with semiconductor crystals suggests that the transducer is best suited to be acted on by a device or medium of high mechanical impedance. For microphones, the impedance matching problem becomes critical due to the small acoustic impedance of air. Accordingly, the following dynamic considerations are of interest.

The output of any microphone depending on the piezoresistive effect is proportional to the displacement of the active element. If a force of magnitude F_0 and angular frequency ω is applied to a transducer of mechanical impedance Z , then the velocity v of the moving element is:

$$(1) \quad v = \frac{F_0}{Z}$$

If the transducer is stiffness-controlled (i.e., operated below the first resonant frequency), then:

$$(2) \quad Z = \frac{S}{j\omega}$$

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where S is the stiffness of the transducer (dynes per centimeter). Therefore, from (1) and (2):

$$(3) \quad V = \frac{j\omega F_0}{S}$$

but

$$(4) \quad v = j\omega x$$

where x is the displacement of the moving element; therefore:

$$(5) \quad x = \frac{F_0}{S}$$

Thus, a vibrating system operating under the fundamental frequency has the same deflection as if it were statically loaded. This condition yields a flat output versus frequency curve since the incremental change in resistance is directly proportional to the strain sustained by the semiconductor.

For microphones utilized in telephone systems, it is acceptable to have a frequency response which is relatively flat up to a resonance at about 2900 cycles per second. Such a response serves as a guide for the selection of circuit parameters in the present illustrative embodiment.

A diaphragm 14 of the type described with reference to element 18, which is similar to that used in telephone sets of the most recent design, has an effective mass of .16 gram. In order to operate at a resonance frequency of 2900 cycles per second, the crystal rod 18 should have a stiffness of $50 \cdot 10^6$ dynes per centimeter, as determined by substitution in the formula:

$$(6) \quad f = \frac{1}{2\pi\sqrt{\frac{M}{S}}}$$

where f is the frequency, M is the mass in grams and S is the stiffness.

To provide a stiffness of the magnitude indicated, an indium antimonide crystal rod 1 centimeter long should have a cross-sectional area of 10^{-4} square centimeters. Moreover, since indium antimonide has a resistivity ρ of approximately .01 ohm-centimeter at room temperature, it is apparent by substituting the dimensions given in the formula

$$R = \frac{\rho l}{A}$$

where l is the length and A is the cross-sectional area, that the rod 18 has a resistance of about 100 ohms. It will be noted that this resistance is of the right order of magnitude to work conveniently into the input terminals of a transistor amplifier.

If the microphone operates in a sound field of 10 microbars pressure, and the effective area of the diaphragm 13 is 10 square centimeters, then the force F_0 , which the diaphragm exerts on the rod 18, may be computed as follows:

$$(7) \quad F_0 = p \cdot A_{\text{eff}}$$

where p equals the pressure of the sound field and A_{eff} equals the effective area of the diaphragm. Substituting the values given above, in equation 7, F_0 is determined to be 100 dynes.

In the microphone of the present invention, as described with reference to Fig. 1, the crystal rod element 18 is operated under a condition of simple tension. As previously discussed, this is brought about by fixing one end of the rod 18 in shaft 17, and fixing the other end of rod 18 in a slot in the button 15 of diaphragm 14, while the latter is distorted by a mass temporarily placed on the upper surface just above the contact button. The mass must be large enough to produce in the rod 18, when the mass is removed, a tension which exceeds the maximum applied sound force. Since a sound pressure of 10 microbars has been shown to produce a force of

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100 dynes on the diaphragm, it is apparent that the biasing force should be substantially in excess of this. Thus, for example, a 1 gram mass, which produces a force of 980 dynes, would be suitable for this purpose. In any case, the biasing force should not be large enough to alter the acoustic properties of the diaphragm. In the case of the present illustrative embodiment, the upper limit is about 3 grams.

In further discussing the operating characteristics of a 10 microphone of the design described with reference to Fig. 1, several terms are of interest, which are defined as follows:

(a) Young's Modulus

$$15 \quad Y = \frac{\text{stress } (X)}{\text{strain } (e)}$$

where X is the applied stress in dynes per square centimeter, and e represents the ratio of the change in length Δl , to the length l , of the rod. The units of Y are dynes per square centimeter.

(b) Piezoresistive coefficient

$$20 \quad K_p = \frac{\Delta \rho}{\rho} / X$$

where ρ is the resistivity in ohm-centimeters, $\Delta \rho$ is the change in resistivity, and X is the applied stress in dynes per square centimeters. The units of K_p are centimeters squared per dyne.

From (a) and (b) above, the following definition is derived:

$$(c) \quad \text{Strain Gage Factor } G = YK_p = \frac{\Delta \rho}{\rho} \cdot \frac{1}{e}$$

Neglecting the slight effect which the change in dimensions produces on the resistance, the above becomes:

$$(d) \quad G = \frac{\Delta R}{R} \cdot \frac{1}{e}$$

where

$$40 \quad R = \frac{\rho l}{A}$$

and

$$45 \quad e = \text{the strain} = \frac{\Delta l}{l}$$

The strain gage factor, which is a measure of the piezoresistive effect in semiconductors, is a ratio without units. In single crystal indium antimonide, its value is about 40.

The strain gage factor G , together with several other parameters which will presently be computed, will be used to determine the signal output voltage L at constant current bias, in accordance with the following formula

$$55 \quad (8) \quad L = IRGe$$

where I is the bias current; R is the resistance of rod 18; and e is the strain,

$$\frac{\Delta l}{l}$$

The change in the length of the rod, Δl is determined by substituting the values derived earlier, in Equation 5:

$$60 \quad x = \frac{F_0}{S} = \frac{100 \text{ dynes}}{50 \cdot 10^6 \text{ dynes/cm.}} = 2 \cdot 10^{-6} \text{ centimeters}$$

Since the length l is 1, the strain e is $2 \cdot 10^{-6}$.

In the presently described embodiment, the magnitude of the operating current bias is determined by noise considerations. In the case of indium antimonide, however, the signal-to-noise ratio is very high (of the order of 20 decibels better than in other semiconductors), the only noise being due to thermal agitation ("Johnson noise") within the lattice structure; hence the biasing current may be relatively low. However, in order for the biasing

power requirements to be compatible with the requirements of a solid state switching system, a biasing current of about 3 milliamperes has been chosen for use in the present illustrative example.

Substituting the foregoing values in Equation 8, the signal output voltage, at constant current bias, is as follows:

$$L=IRGe=3 \cdot 10^{-3} \cdot 100 \cdot 40 \cdot 2 \cdot 10^{-6}=24 \cdot 10^{-6} \text{ volts}$$

From the standpoint of power output, the embodiments described are admittedly less efficient than the carbon microphone. However, the power ordinarily used to bias the carbon microphone can be more advantageously used in a telephone system to bias a transistor amplifier, which is about 40 percent efficient. Moreover, as previously indicated, the microphone of the present invention is uniquely impedance matched to the input of a transistor amplifier. Accordingly, the high degree of inherent linearity of the present device is considered of greater importance, from a practical standpoint, than its comparative inefficient power output.

In accordance with a modification of the present invention, a microphone is constructed comprising a rectangular bimorph element of two plates of indium antimonide which makes use of the piezoresistive effect in a semiconductor element when a force is applied to one corner of the bimorph, driving them to move in the direction of the applied force, while the other three corners on the lower plate are held rigid, thereby causing a shear deformation in the element.

Such a device is indicated schematically in Figs. 3A through 3F of the drawings. Referring in detail to Fig. 3A, the bimorph element 20 comprises a pair of plates of polycrystalline indium antimonide sliced from ingots having an impurity carried concentration of not greater than 10^{16} per cubic centimeter, which are obtainable commercially from the Ohio Semiconductor Company, Columbus, Ohio. A pair of matched plates, substantially square, measuring a little over 1 centimeter on an edge, and each having a thickness of about 500 microns, are cemented together with a layer about 50 microns thick of an insulating material such as, for example, one of the class of materials known in the art as epoxy resins. An epoxy resin is prepared to have the proper consistency and drying properties for the purpose of the present invention by adding an accelerator or drying agent, and then allowing the layer to harden, after the two plates have been properly disposed in face-to-face matched position.

The bimorph element 20 is then mounted in a frame 23 of lightweight conducting metal, such as aluminum, which is in general similar to that described with reference to Fig. 1 of the drawings. The four corners of the upper plate of element 20 are designated 1, 2, 3 and 4; and the corresponding four corners of the lower plate are designated 5, 6, 7 and 8. The three lower corners 5, 6, and 7 are rigidly mounted on supports which are insulated from, and which project several millimeters above the base plate 22 of frame 23, by means of indium or indium alloy solder, such as described with reference to Fig. 1. Lower corner 8 of the bimorph element 20 is disposed to swing freely in response to pressure applied to the surface of the corresponding upper corner 4 by the button 24 of the microphone diaphragm 25, to which button the corner 4 has been soldered with indium or indium alloy solder. The diaphragm 25, and its manner of mounting in the frame 23, is similar to that described with reference to the structure of Fig. 1. Figs. 3B and 3C, respectively, show the manners in which the upper and lower plates of the bimorph element 20 tend to become distorted in response to pressure from the microphone button 24 on the upper corner 4, sustaining, in each case, a shear deformation, oppositely directed along the diagonals of the upper and lower rectangular plates. These deformations, in turn, produce substantial piezo-

resistive variations along the diagonal directions between points 2 and 3 on the upper plate, and points 6 and 7 on the lower plate, which are oppositely directed, and hence develop transverse voltages of opposite signs across these respective pairs of points when the biasing voltage is in the same direction in both.

Three alternative types of circuit connections linking the upper and lower plates and the biasing battery to the output are indicated in Figs. 3D, 3E, and 3F. In each case, the connecting leads are soldered to the surface of the elements by means of indium or indium alloy solder.

Fig. 3D shows a series connection of the generated voltages, in which a bias battery 26 large enough to provide a bias current of about .1 ampere, in the case of indium antimonide. Bias battery 26 has its positive terminal connected to the corner or point 5 on the lower plate, and its negative terminal to point 1 on the upper plate. Point 4 on the upper plate and point 8 on the lower plate are connected together. The positive output terminal is connected to point 6 on the lower plate, and the negative output terminal to point 3 on the upper plate.

Fig. 3E shows a parallel-connection of the generated voltage in which a bias battery 26, providing about the same current described above, is connected with its positive pole to point 5 on the lower plate, and its negative pole to point 1 on the upper plate. Point 4 on the upper plate is connected to point 8 on the lower plate, and point 3 to point 7. The positive output terminal is connected to point 6, and the negative output terminal to point 3.

Fig. 3F shows the upper and lower plates, respectively, connected as the two arms of a bridge circuit. The balancing resistance arms 27 and 28, having magnitudes of the order of 1 ohm each, are joined at point 30, which is connected directly to one of the output terminals. Point 6 on the lower plate is connected to the other terminal of resistance arm 28, and point 2 on the upper plate is connected to the other terminal of resistance arm 27. Points 3 and 7 on the upper and lower plates, respectively, are connected together to the second output terminal.

Since indium antimonide has a piezoresistive characteristic which is isotropic, the orientations of crystal plates of that material in the embodiment just described are not critical. However, should other semiconductor materials, such as germanium and silicon, be substituted for indium antimonide in the embodiment just described, they should comprise plates so oriented that the piezoresistive effect in response to shear deformation is a maximum in the desired direction. The following table indicates the optimum orientation of the crystal plates.

Table 1

Material	Boundary direction on crystal plates	Crystallographic direction
N type silicon	1 → 2	[100]
	1 → 3	[010]
P type silicon	1 → 2	[110]
N and P type germanium	1 → 3	[110]

In the case of germanium and silicon, the voltage of the bias battery 26 is limited by noise conduction in the material. A practical value for the embodiments described is about 10 volts per centimeter of thickness of the crystal plate.

It will be apparent to those skilled in the art that the present invention is not restricted to the specific embodiments described herein by way of illustration.

What is claimed is:

1. An electromechanical translating device which comprises in combination a reference frame, a diaphragm movable with respect to said frame, and a rod of crystal-

line indium antimonide longitudinally interposed under a tension bias between a movable point on said diaphragm and said reference frame, and an electrical circuit including a source of power and an output circuit electrically interconnected with said indium antimonide rod, whereby mechanical movement of said diaphragm is translated by the piezo-resistive effect of said rod into variation in the flow of current from said source to said output circuit.

2. A combination in accordance with claim 1 wherein said rod comprises polycrystalline indium antimonide.

3. A device which comprises in combination microphone having a diaphragm, a fixed reference frame, a bimorph element comprising an upper and a lower rectangular semiconductor crystal plate cemented together in matched face-to-face relation with an insulating layer between said faces, said bimorph element disposed with three corners on said lower plate of said element rigidly fixed to said frame, the fourth corner on said lower plate disposed to swing freely, and the fourth corner on said upper plate disposed in relation to said diaphragm to sustain a shear deformation in said bimorph in response to motion of said diaphragm, and an electrical circuit including a source of substantially constant electric power, and an output impedance connected in electrical circuit relation with said bimorph, whereby motion of said diaphragm is translated by the piezo-resistive effect of said bimorph element into variation in the flow of current from said source to said output impedance.

4. A combination in accordance with claim 3 wherein said semiconductor crystal plates comprise indium antimonide.

5. A microphone comprising in combination a rigid frame, a deformable diaphragm including peripheral portions mounted in substantially fixed relation to said frame wherein the central portion of said diaphragm is constrained to move in a direction substantially normal to its surface, a rod of piezoresistive monocrystalline semiconductor material connected under an initial tension bias between the central portion of said diaphragm and a fixed position on said frame and disposed in rigid tensile relation with respect to said diaphragm so that the prin-

cipal stress components due to the motion of said diaphragm are applied in the direction of elongation of said rod, and contact means respectively connected in electrical conducting relation to a pair of longitudinally separated points on said rod.

6. A microphone comprising in combination a rigid frame, a deformable diaphragm including peripheral portions mounted in substantially fixed relation to said frame wherein the central portion of said diaphragm is constrained to move in a direction substantially normal to its surface, a rod of piezoresistive crystalline material comprising indium antimonide connected in rigid tensile relation between the central portion of said diaphragm and a fixed position on said frame so that the principal stress components due to the motion of said diaphragm are applied in the direction of elongation of said rod, and contact means respectively connected in electrical conducting relation to a pair of longitudinally separated points on said rod.

7. A microphone in accordance with claim 6 wherein said indium antimonide material is polycrystalline.

8. A device for translating variations in applied acoustic power into variations in electric current comprising in combination a translating member, a reference frame, a piezoresistive element of crystalline indium antimonide mounted between said translating member and said frame, and an electrical circuit including a source of electric power and an output circuit connected through said piezoresistive element whereby variations in acoustic power being transmitted as stress variations by said translating member to said piezoresistive element produce corresponding changes in the electrical resistance of said piezoresistive element, thereby determining the flow of current from said source to said output circuit.

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