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H. C. MONTGOMERY
SEMICONDUCTOR TRANSDUCER

2,632,062

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FIG. 1

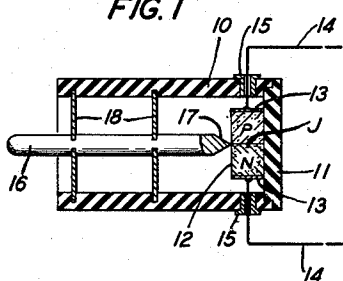


FIG. 2

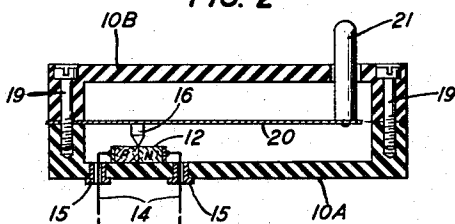


FIG. 3

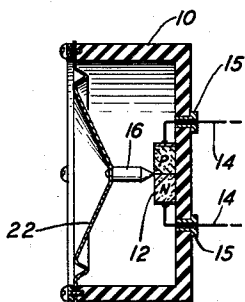


FIG. 4

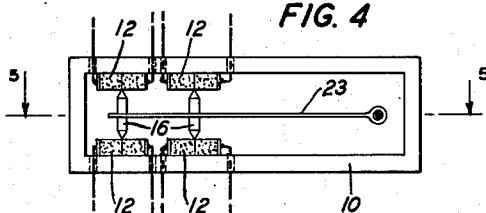


FIG. 5

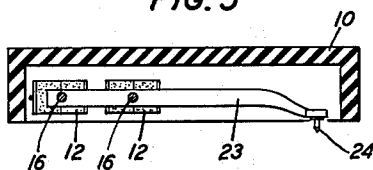
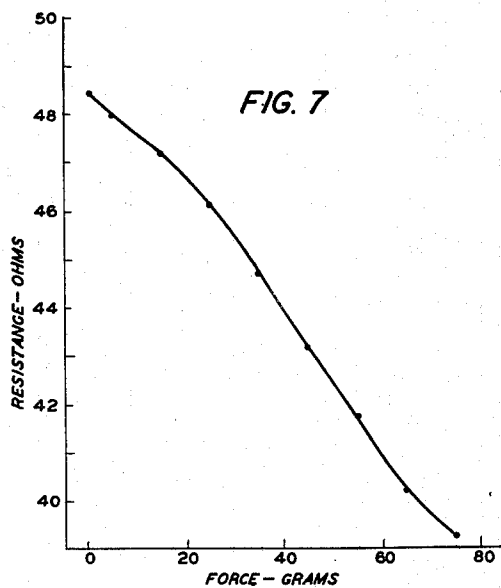
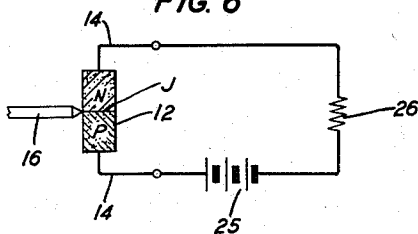


FIG. 6



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SEMICONDUCTOR TRANSDUCER

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5 Claims. (Cl. 179-121)

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This invention relates to semiconductor transducer and more particularly to such devices including semiconductive materials.

General objects of this invention are to simplify the construction and improve the performance of electromechanical transducers such as microphones, phonograph pickups and the like. More specific objects of this invention are to effect high fidelity translation of acoustic or mechanical variations into electrical signals, to obtain stable operation of electromechanical transducers, and to realize uniform performance over a long operating life for such devices.

The invention is predicated in part upon the discovery that an NP junction in a body of semiconductive material, such as germanium or silicon, when subjected to pressure, effects a variation in the resistance between two points on the body on opposite sides of the junction. Such a junction obtains at the interface of two zones of opposite conductivity type, N and P, in a body of semi-conductive material and may be produced in germanium in the manner disclosed in the application, Serial No. 638,351, filed December 29, 1945, now Patent 2,602,211, granted July 8, 1952 of J. H. Scaff and H. C. Theuerer and in silicon as disclosed in Patents 2,402,661, dated June 25, 1946 and 2,402,662, dated June 25, 1946 of R. S. Ohl.

In one illustrative embodiment of this invention, an electromechanical transducer comprises a body or slab of semi-conductive material having therein a PN junction which extends to at least one face of the body, and a pair of electrical connections to the body on opposite sides of the junction. It comprises also an actuating member, which may be of electrically conducting or insulating material, having a pointed end bearing against the junction, the actuating member being mounted for vibration to vary the pressure of it upon the junction and coupled to a driving element, for example, a diaphragm of a microphone or stylus of a phonograph pickup. Variations in the pressure result in corresponding changes in the resistance across the junction and, hence, similar changes in the current flowing between the pair of connections to the body. The relation between resistance and force or pressure on the junction is substantially linear over a range of pressures. Furthermore, the response is uniform over a wide range of frequencies.

The invention and the features thereof will be understood more clearly and fully from the following detailed description with reference to the accompanying drawing in which:

Fig. 1 is an elevational view in section of an

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electromechanical transducer constructed in accordance with this invention;

Fig. 2 is a sectional view of another transducer constructed in accordance with this invention, including an actuating system producing large pressure changes on the junction;

Fig. 3 illustrates a microphone embodying features of this invention;

Figs. 4 and 5 are sectional views in planes normal to each other of a phonograph pickup illustrative of another embodiment of this invention;

Fig. 6 is a schematic showing a typical circuit including a transducer constructed in accordance with this invention; and

Fig. 7 is a graph depicting a typical resistance-force characteristic for devices of the construction illustrated in Figs. 1 to 5.

Referring now to the drawing, the electromechanical transducer illustrated in Fig. 1 comprises a housing 10, for example of insulating material, having a base 11 upon which a slab or block 12 of semiconductive material is affixed. The semiconductive body 12 has therein a barrier or junction J on one side of which the material is of P conductivity type and on the other side of which the material is of N conductivity type, as illustrated by the letters N and P in Fig. 1. Ohmic connections 13 which may be, for example, platings of rhodium or the like, are made to the body, for example to the ends thereof, on opposite sides of the junction J. Leading-in conductors 14 extend from the connections 13 and through eyelets 15 in the wall of the casing 10.

An actuating member 16, which may be of electrically conductive or insulating material, has a pointed end portion 17 bearing against the junction J. The tip of the pointed portion may be, for example of the order of .001-inch radius. The actuating member 16 is mounted for reciprocable vibration or movement by a pair of resilient members 18 having high stiffness in their planes and low stiffness in the direction normal to their planes. These members 18 may be, for example, thin metallic spiders, the peripheries of which are affixed to the casing 10 and the inner ends of the arms of which are joined to the actuating member 16.

Axial displacement or vibration of the actuating member 16 alters the force or pressure upon the junction J and results in a corresponding variation in the resistance of the semiconductive body between the two electrodes 13 and consequently in variations in current passing to a circuit connected to the conductors 14.

The embodiment of the invention illustrated in

Fig. 2 is generally similar to that illustrated in Fig. 1 and described hereinabove but is particularly advantageous for use in cases where low mechanical stiffness of the vibrating system is necessary or desired. As shown in Fig. 2, the actuating member 16 is supported by a lever 20, one end of which is clamped between the two parts 10A and 10B of the housing, these parts being secured together as by screws 19. The lever is driven by a member 21 affixed thereto adjacent its free end thereby to vary the pressure of the actuating member 16 upon the PN junction in the semiconductor body 12.

Fig. 3 illustrates a microphone constructed in accordance with this invention and comprising a diaphragm 22 which supports the actuating member 16 for axial reciprocation.

The phonograph pickup illustrated in Figs. 4 and 5 comprises four semiconductor bodies 12 arranged in two pairs with the PN junctions of the bodies of each pair aligned with each other. Two actuating members 16 are provided each having its opposite ends pointed and bearing against the junctions in the respective pair of semiconductor bodies 12. The actuating members are mounted upon the arm 23 which carries the stylus 24 and is laterally vibratile. Lateral motion of the stylus 24 in the groove of a record varies the forces on all of the junctions in the four bodies 12, increasing the force on two and decreasing the force on the other two. The several bodies 12 may be connected in push-pull relation to combine the electrical outputs thereof in phase whereby an output signal corresponding to the vibration of the stylus 24 is obtained.

The general circuit including devices of constructions illustrated in Figs. 1 to 5 and heretofore described is illustrated in Fig. 6. A suitable bias is applied across the body 12 by a direct-current source 25 in series with a load which is illustrated, for simplicity, as a resistor 26. As has been described heretofore, changes in the pressure between the actuating member 16 and the PN junction J vary the resistance between the conductors 14 and thus result in a corresponding variation of current through the load 26.

Typical operating characteristics of devices constructed in accordance with this invention are illustrated in Fig. 7. As is apparent from this figure, wherein force on the junction is plotted as abscissae and resistance between the electrodes or connections 13 is plotted as ordinates, the relation between force and resistance is substantially linear over a very wide range of forces. It will be understood, of course, that in any of the devices illustrated and described the actuating member 16 may be adjusted so that a normal pressure of prescribed magnitude obtains between the pointed end 17 and the junction J whereby the device may be operated along a desired part of the resistance-force characteristic illustrated in Fig. 7.

In addition to the linear force-resistance relation indicated, the response of devices constructed in accordance with this invention is uniform over a wide range of frequencies, for example, in a typical device from zero to 13,000 cycles and higher.

It will be appreciated that not only do devices constructed in accordance with this invention enable high fidelity translation of mechanical or acoustic variations into electrical signals but also the devices are characterized by simplicity and facility of construction. Further-

more, semiconductor bodies such as germanium and silicon are quite stable so that such devices have the advantage of freedom from aging effects.

Although specific embodiments of this invention have been shown and described, it will be understood that they are but illustrative and that various modifications may be made therein without departing from the scope and spirit of this invention.

What is claimed is:

1. An electromechanical transducer comprising a body of semiconductor material having therein an NP junction which extends from one face of said body, electrical connections to regions of said body on opposite sides of said junction, an actuating member bearing against said junction at said face and electrically inert with respect to said body, and means for operating said member to vary the pressure thereof against said junction.

2. An electromechanical transducer comprising a body of semiconductor material having therein an NP junction, substantially ohmic electrical connections to said body on opposite sides of said junction, and means including an actuating member bearing against said body and electrically inert with respect to said body for subjecting said junction to varying pressure.

3. An electromechanical transducer comprising a body of semiconductor material having therein an NP junction which extends from one face of said body, substantially ohmic electrical connections to said body on opposite sides of said junction, an actuating member having a point portion bearing against said junction at said face, and means for vibrating said member to vary the pressure between said portion and said junction.

4. An electromechanical transducer comprising a pair of bodies of semiconductor material, each body having therein an NP junction extending from one face thereof, said bodies being mounted with the faces thereof from which the junctions extend, in spaced opposed relation, electrical connections to each body on opposite sides of the junction therein, a pair of insulating actuating members between said faces and each bearing against a respective one of said junctions, and driving means coupled to said members for vibrating both said members simultaneously.

5. A microphone comprising a body of semiconductor material having therein an NP junction which extends from one face thereof, an actuating member bearing against said junction at said face, diaphragm means coupled to said member for vibrating it to vary the pressure exerted upon said junction by said member, and electrical connections to said body on opposite sides of said junction.

HAROLD C. MONTGOMERY.

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