

May 15, 1951

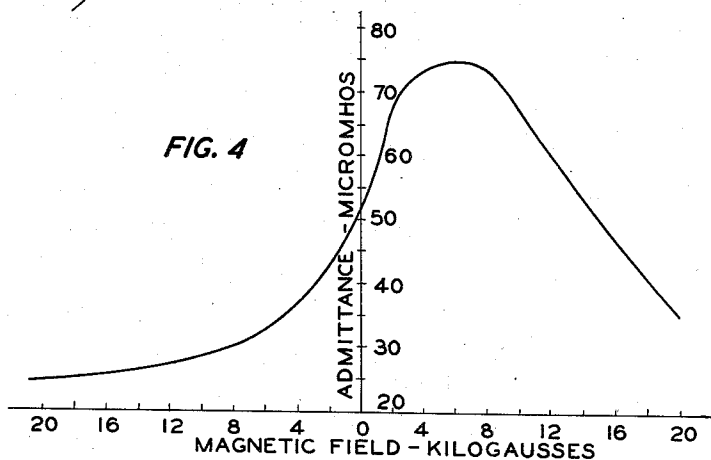
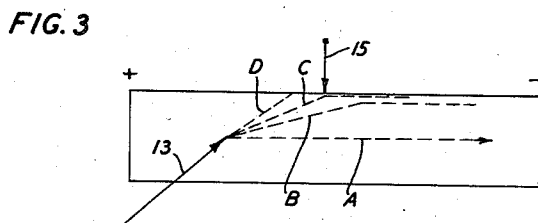
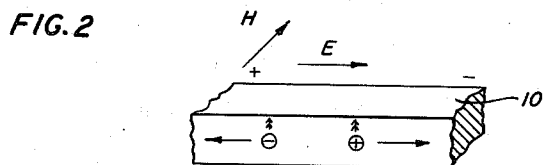
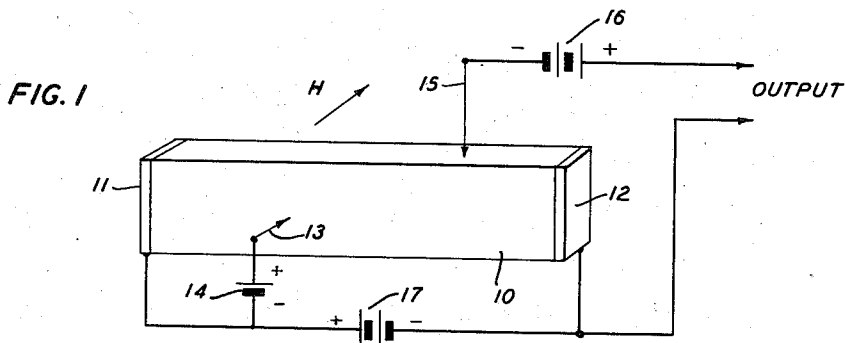
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2,553,491

ACOUSTIC TRANSDUCER UTILIZING SEMICONDUCTORS

Filed April 27, 1950

2 Sheets-Sheet 1



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FIG. 5

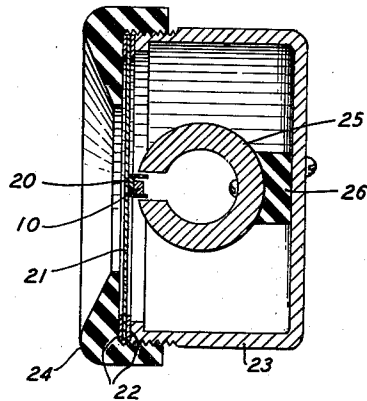


FIG. 6

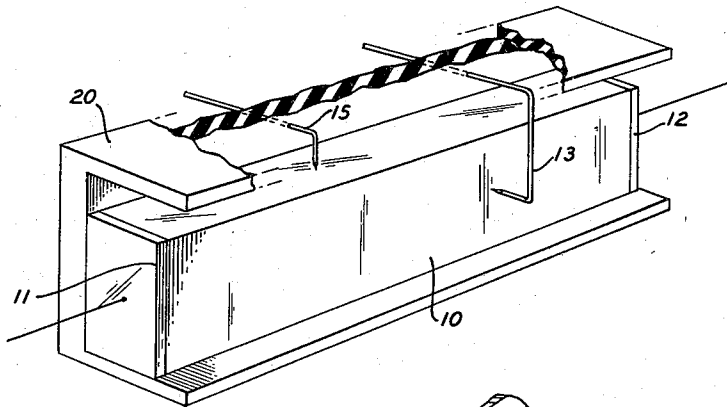
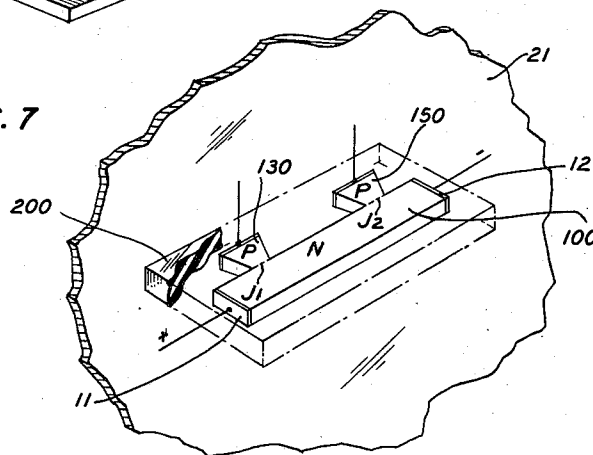


FIG. 7



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ACOUSTIC TRANSDUCER UTILIZING
SEMICONDUCTORS

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Application April 27, 1950, Serial No. 158,519

7 Claims. (Cl. 171-330)

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This invention relates to electromechanical transducers and more particularly to acoustic devices including semiconductor translating elements.

One object of this invention is to simplify the structure of electromechanical transducers. Another object of this invention is to improve the performance, notably to realize gain concomitantly with translation of mechanical to electrical variations, of acoustic devices such as microphones.

In one illustrative embodiment of this invention, an electromechanical transducer comprises a body, for example a filament, of germanium mounted for vibration in accordance with a pressure responsive element. For example, the germanium filament may be coupled mechanically to the diaphragm in a microphone for bodily vibration therewith. Associated with the body or filament, or forming a part thereof, are a pair of spaced electrical connections, one for injecting electrical carriers into the body and the other for obtaining an output current from the body. The germanium element is subjected to crossed magnetic and electric fields, the latter field being in the direction of the spacing of the two connections and of the polarity to accelerate the injected carriers toward the output connection. The magnetic field is normal to this direction and parallel to the direction of vibration of the filament or body and is of such character and relation to the body that as the latter vibrates the strength of the magnetic field to which it is subjected varies as a function of displacement of the body.

As will be described in detail hereinafter, it has been found that the admittance of the output connection is a function of the magnetic field extant in the region between the two connections. Hence, vibration of the filament or body results in variations in the output connection admittance and this in turn is utilizable to vary the current in the output circuit correspondingly. Thus, mechanical vibrations of the semiconductor translating element are transformed into electrical variations representative thereof.

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 a diagram illustrating the principal components of the semiconductor translating element included in transducers constructed in accordance with this invention;

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Figs. 2 and 3 are diagrams which will be referred to hereinafter in the discussion of certain principles involved in the operation of devices constructed in accordance with this invention;

Fig. 4 is a graph depicting the relationship between output connection admittance and magnetic field strength in such devices;

Fig. 5 is an elevational view in section of a microphone illustrative of one embodiment of this invention;

Fig. 6 is a perspective view to an enlarged scale of the semiconductor unit and the mount therefor included in the microphone shown in Fig. 5; and

Fig. 7 is a perspective view to an enlarged scale of a semiconductor unit illustrative of another embodiment of this invention.

Referring now to the drawing, the translating element illustrated in Fig. 1 comprises an elongated body or filament 10 of semiconductive material, having ohmic connections 11 and 12, for example rhodium platings, at opposite ends thereof. Bearing against one of the major faces of the body or filament 10 is a point contact 13 which is biased in the forward direction relative to the body by a source 14. A second point contact 15 bears against one of the sides of the body 10 and is biased with respect to the body by a suitable source 16. An electric field threading the body 10 longitudinally is produced by a source 17 connected between the ohmic platings 11 and 12. The output circuit, not shown, is coupled between the connection 12 and the point contact 15. Means, also not shown in Fig. 1, are provided for producing a magnetic field traversing the body transversely, the direction of the field being indicated by the arrow H in the figure.

The admittance of the point contact 15, it has been found, is a function of the magnetic field H, the relationship for a typical device being as shown in Fig. 4. In this particular device, the semiconductive body 10 was a filament of N conductivity type germanium, 0.025 centimeter wide (width being measured vertically in Fig. 1) and 0.025 centimeter thick, and the point contacts 13 and 15 were of Phosphor bronze and spaced 0.13 centimeter. The germanium material was prepared as described in the application Serial No. 638,351, filed December 29, 1945, of J. H. Scaff and H. C. Theuerer. Other significant data for this device, resulting in the specific characteristic shown in Fig. 4, are that a fixed current of 5 milliamperes was passed through the filament longitudinally, 3 milliamperes of this current being supplied from the contact 13, and the resist-

ance of the contact 15 was determined by measuring the voltage applied to this contact and requisite to produce a current of 10 microamperes therein. The magnetic field H was varied and the corresponding changes in resistance noted.

The effect depicted in Fig. 4 is distinct from the Hall effect for the latter involves current of charges of only one sign (negative) in the body. In semiconductive devices of the type comprehended by this invention, on the other hand, electric carriers of both signs, specifically positive holes and negative electrons, are present. Consideration of some basic principles will emphasize this distinction and provide a basis for an explanation of the phenomena involved in the production of a characteristic of the form illustrated in Fig. 4.

A semiconductive body, such as the filament 10 in Fig. 1, has therein an excess of carriers or charges of one sign, the sign depending upon or being determinative of the conductivity type of the material. Specifically, if the body is of N conductivity type material, the carriers in excess are electrons, whereas if the material is P type the carriers in excess are holes. A point contact, such as the contact 13 in Fig. 1, appropriately biased relative to the body results in the injection into the body of carriers of the sign opposite those normally present in excess in the body.

For purposes of analysis, a device such as shown in Fig. 1, and wherein the body 10 is of N conductivity type, may be taken as typical, for similar considerations apply also to a body of P type material. For the N type case, the carriers injected at the contact 13 are positive holes. The total current in the body is composed of (a) conduction electrons and (b) holes and corresponding electrons. As illustrated in Fig. 2, wherein the plus circle represents a hole and the minus circle an electron, because of the longitudinal electric field E the holes and electrons are subjected to forces parallel to this field, the absolute directions being opposite and indicated by the single headed arrows. However, because of the transverse magnetic field, both holes and electrons are subjected to second forces, in the same direction as indicated by the double headed arrows. It will be seen, then, that holes and electrons will concentrate on the upper surface of the body 10, in Fig. 2. The consequent increased carrier density at this surface leads to a reduction in the impedance of an appropriately positioned contact such as 15.

The maximum in the curve presented in Fig. 4 may be explained by an analysis with particular reference to Fig. 3. With no magnetic field present, the flow of carriers in the semiconductive body is along paths the median of which is indicated by line A. For a magnetic field below that corresponding to the maximum of the curve of Fig. 4, the median path is of the position illustrated by line B in Fig. 3, and some of the carriers reach the contact 15. If the magnetic field is of a certain strength, the median path is as indicated by line C and the maximum number of carriers flow to the vicinity of the contact 15 and the admittance of this contact is a maximum as shown in Fig. 4. For greater magnetic fields, the carriers are directed to one side of the contact 15, the median path being represented by line D. Because of recombination effects, the number of carriers which reach the contact 15 is reduced, compared to the number corresponding to the condition represented by line C. Thus; it

will be manifest that the admittance of the point 15 will vary with magnetic field strength, the variation for a typical device being, as noted heretofore, shown in Fig. 4.

The variation in admittance obtains, it has been found, for both polarities of bias upon the point 15. It has been found further that the decrease in admittance of the point contact 15 when a negative magnetic field, i. e. of the direction to produce a downward force in Fig. 2, is applied, is substantially greater when the contact 15 is biased in the forward direction than when the contact is operated in the reverse direction. In some applications, however, bias in the reverse direction is advantageous as it leads to enhanced gain.

The invention may be embodied in telephone transmitters or microphones, a typical construction being illustrated in Fig. 5. As shown in this figure and in Fig. 6, the semiconductive body or filament 10 is mounted in a channel-shaped insulated mount or support 20 which is affixed to a diaphragm 21. The diaphragm 21 together with the spacing rings 22 is affixed against the open end of a cup-shaped housing 23 by a cap or mouthpiece 24 threaded to the housing. The point contacts 13 and 15 bear against the body 10 and are fitted in openings in the mount 20.

The semiconductive body 10 is positioned in the gap in a generally toroidal magnet 25 which is affixed to the base of the housing 23 and spaced therefrom by an insulating member 26.

In response to the vibrations of the diaphragm 21, the semiconductive body 10 is vibrated in the magnetic field between the pole faces of the magnet 25 whereby the strength of the magnetic field threading the semiconductive body is varied. Such variation in field strength, as has been discussed hereinbefore, results in corresponding changes in the admittance of the point contact 15. Such change in admittance modifies correspondingly the current flowing in the output circuit associated with the point contact 15 and the body 10 in the manner illustrated in Fig. 1. Thus, vibrations of the diaphragm 21 in accordance with sound waves incident thereupon are translated into corresponding electrical variations in the output circuit.

Advantageously the strength of the magnet 25 is such that the microphone is operated at a point to the right of the maximum of the characteristic depicted in Fig. 4 whereby a substantial linear relationship obtains between changes in admittance of the point contact 15 and displacement of the semiconductive body 10 in the magnetic field.

In another embodiment of this invention, illustrated in Fig. 7, the semiconductive element is of the type disclosed in Patent 2,502,479, granted April 4, 1950, to G. L. Pearson and W. Shockley and application Serial No. 50,894, filed September 24, 1948, of J. R. Haynes and W. Shockley. It comprises a germanium filament having a portion 100 of N conductivity type and two projecting portions 130 and 150 of P conductivity type integral with the portion 100 and defining rectifying junctions J₁ and J₂ therewith. Substantially ohmic connections are made to the opposite ends of the portion 100 and to the outer ends of the portions 130 and 150. The germanium element is encased in a body 200 of plastic and joined thereby to the diaphragm 21. As in the device illustrated in Figs. 5 and 6, in the embodiment illustrated in Fig. 7 vibration of the germanium element with the diaphragm and in the air gap

of a magnet, such as the magnet 25 shown in Fig. 5, results in variation of the admittance of the output connection 150 and consequent variation in the current flowing in the output circuit connected, for example, between elements 150 and 12.

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 semiconductive material, means for injecting current carriers into said body at one region thereof, an output connection to said body at a region spaced from said one region, means for establishing in said body an electric field threading it in the direction of the spacing of said regions, means for producing a magnetic field threading said body substantially normal to said electric field, and means for vibrating said body in the direction substantially normal to said electric and magnetic fields.

2. An electromechanical transducer comprising a filament of semiconductive material, means for injecting current carriers into said filament including a rectifying connection to said filament adjacent one end thereof, an output connection to said filament at a region spaced longitudinally of said filament from said rectifying connection, means for establishing in said filament an electric field extending longitudinally thereof, means for producing a magnetic field threading said filament transversely, and means for vibrating said filament in the direction substantially normal to said electric and magnetic fields.

3. An electromechanical transducer comprising a filament of germanium, means for injecting current carriers into said filament including a rectifying connection to said filament adjacent one end thereof, an output connection to said filament at a region spaced longitudinally of said filament from said rectifying connection, means for establishing in said filament an electric field extending longitudinally thereof, means for producing a magnetic field threading said filament transversely, and means for vibrating said filament in the direction substantially normal to said electric and magnetic fields.

4. An electromechanical transducer comprising a filament of N conductivity type germanium, a pair of rectifying connections to said filament adjacent opposite ends thereof, means for establishing in said filament an electric field extending longitudinally thereof, means for producing a magnetic field for threading said filament transversely, and means for vibrating said filament to vary the magnetic field threading it.

5. An electromechanical transducer comprising a filament of semiconductive material, means for injecting electrical carriers into said filament including a point contact bearing against said filament, an output connection including a second point contact bearing against said filament at a point spaced longitudinally of the filament from said first point contact, means for establishing in said filament an electric field extending longitudinally thereof, means for producing a magnetic field normal to said electric field, and means for vibrating said filament in the direction to vary the magnetic field threading said filament.

6. An electromechanical transducer comprising a body of semiconductive material having a first portion of one conductivity type and a pair of other portions of the opposite conductivity type, said other portions being spaced longitudinally of said first portion, contiguous to said first portion and each forming a rectifying junction therewith, means for establishing an electric field threading said first portion longitudinally, means for producing a magnetic field for threading said first portion transversely, and means for vibrating said body to vary the magnetic field threading said first portion.

7. An electromechanical transducer comprising a magnet having a pair of pole faces defining a gap, a body of germanium having an intermediate filamentary portion of N conductivity type adjacent said gap, said body having also portions adjacent opposite ends of said filamentary portion, contiguous thereto and of P conductivity type, means for impressing a potential between the ends of said filamentary portion, and means for vibrating said body in the direction into and out of said gap.

WILLIAM SHOCKLEY.

No references cited.