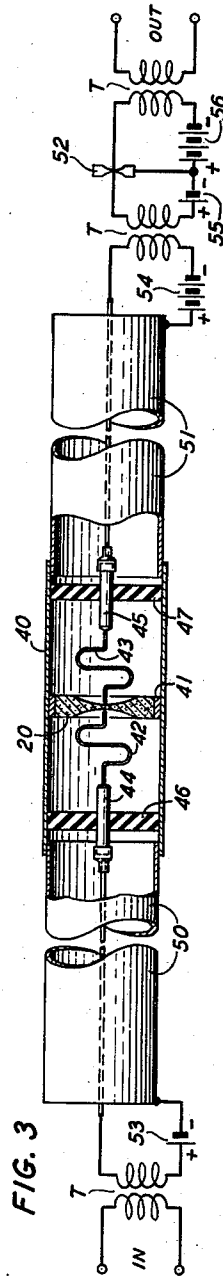
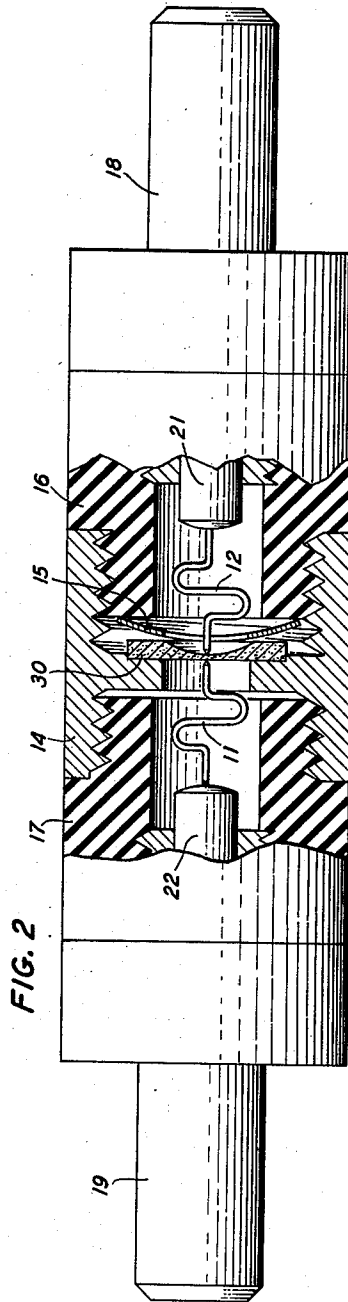
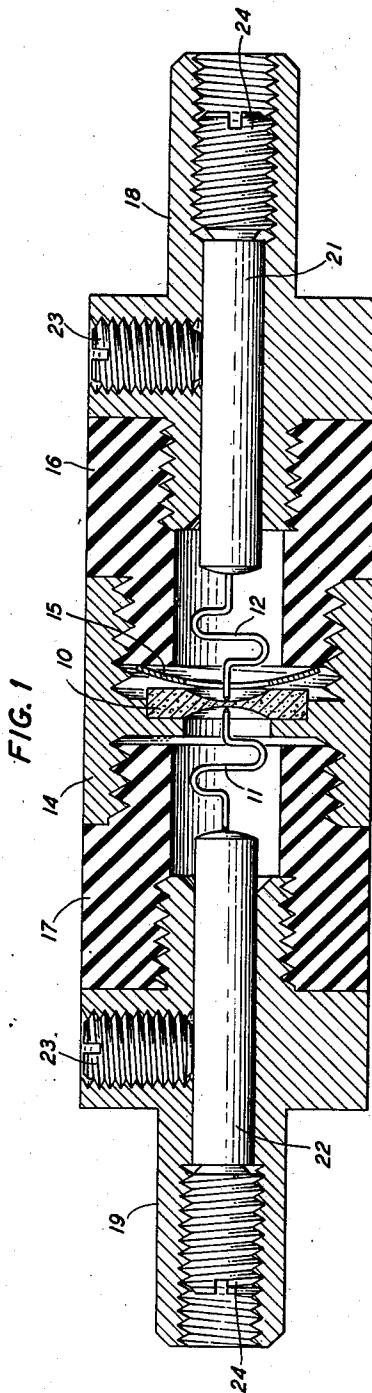


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SEMICONDUCTOR AMPLIFIER

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SEMICONDUCTOR AMPLIFIER

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This invention relates to means for and methods of translating or controlling electrical signals and more particularly to circuit elements utilizing semiconductors and to systems including such elements.

One general object of this invention is to provide new and improved means for and methods of translating and controlling, for example amplifying, generating and modulating, electric signals.

Another general object of this invention is to enable the efficient, expeditious and economic translation or control of electrical energy.

Other and more specific objects of this invention are to improve the structure and operating characteristics of circuit elements including semiconductors, to expedite the manufacture of such elements, to facilitate the realization of preassigned operating characteristics for such elements, and to increase the ruggedness and stability of semiconductor translating members.

In accordance with one broad feature of this invention, translation and control of electrical signals is effected by alteration or regulation of the conduction characteristics of a semiconductive body. More specifically, in accordance with one broad feature of this invention, such translation and control is effected by control of the characteristics, for example the impedance, of a layer or barrier intermediate two portions of a semiconducting body in such a manner as to alter advantageously the flow of current between the two portions.

A further feature of this invention relates to a body of semiconductive material, means for making electrical connection respectively to two portions of said body on opposite sides thereof, means for making a third electrical connection to another portion of the body intermediate said portions, and circuit means including power sources whereby the influence of the third connection may be made to control the flow of current between the other connections.

Another feature of this invention involves a semiconductive body which may be used for voltage and power amplification when associated with means for introducing current to the body at relatively low voltage at a contact called the emitter and extracting current at a relatively high voltage at a contact called the collector.

A further feature of this invention resides in structure for mounting a semiconductive body between two contacts whereby substantially

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colinear contact may be made to opposite faces of the body.

Another feature of this invention resides in a translating device comprising a radially and axially symmetrical disc of semiconductive material mounted in a conductive housing and in electrical contact therewith, and like conductive elements making contact respectively to opposite sides of the disc substantially at the respective ends of the disc axis. Such a structure provides shielding between the contacts on opposite sides of the disc and due to its symmetry is adapted for use at very high frequencies where such configurations are of importance.

In accordance with still another feature of this invention, in a translating device comprising a body of semiconductive material, contacts to opposite faces of said body and a third contact to the periphery of the body, the body is provided with dished or recessed portions in one or both of the opposite faces whereby a section of thickness requisite to produce desired operating characteristics is readily attained concomitantly with a rugged structure wherein realization of colinearity of the opposed contacts is expedited.

The foregoing and other objects and features of this invention will appear more fully and clearly from the following description of illustrative embodiments thereof taken in connection with the appended drawings in which:

Fig. 1 is a sectional view of one form of device illustrating an embodiment of the invention;

Fig. 2 is an elevational view, partly in section, of a device similar to that shown in Fig. 1 but with a different form of semiconductive body; and

Fig. 3 is a diagrammatic illustration of one use of a device in accordance with this invention and includes a sectional view of a structural modification of the devices shown in Figs. 1 and 2.

Translating devices of the type to which this invention pertains may comprise a body of semiconductive material to which at least three separated connections are made. Where three connections are used, two are respectively on opposite sides of the body and a third is made to a portion of the body intermediate these sides. More specifically, if a body configuration which has been successfully operated, i. e. a slab, is considered, the two connections are at substantially opposite points of opposed faces of the slab and the third at an edge between

these faces. Then, if a relatively low voltage is applied between one opposed connection and the third connection so that a relatively low impedance is encountered, and a relatively high voltage is applied between the other opposed connection and the third connection so that a relatively high impedance is encountered, the current introduced at low impedance is extracted at high impedance and amplification results. The connection at which the current is introduced has been named the emitter and that at which the current is extracted the collector. The third connection has been denoted as the base or base electrode.

Devices generally of the type described are disclosed in applications of William Schockley, Serial No. 35,423, filed June 26, 1948 and John N. Shive, Serial No. 44,241, filed August 14, 1948 and theories of operation of such devices are explained in greater detail therein.

Semiconductive materials which have been found suitable for utilization in devices of this invention include germanium and silicon containing minute quantities of significant impurities which comprise one way of determining the conductivity type (either N or P-type) of the semiconductive material. The conductivity type may also be determined by energy relations within the semiconductor. For a more detailed explanation, reference is made to the Patent 2,524,035, granted October 3, 1950 to J. Bardeen and W. H. Brattain.

The terms N-type and P-type are applied to semiconductive materials which tend to pass current easily when the material is respectively negative or positive with regard to a conductive contact thereto and with difficulty when the reverse is true, and which also have consistent Hall and thermoelectric effects.

The expression "significant impurities" is here used to denote those impurities which affect the electrical characteristics of the material such as its resistivity, photosensitivity, rectification, and the like, as distinguished from other impurities which have no apparent effect on these characteristics. The term "impurities" is intended to include intentionally added constituents as well as any which may be included in the basic material as found in nature or as commercially available. Germanium and silicon are such basic materials which, along with some representative impurities, will be noted in describing illustrative examples of the present invention. Lattice effects, such as vacant lattice sites and interstitial atoms when effective in producing holes or electrons are to be included in "significant impurities."

Small amounts of impurities, such as phosphorous in silicon, and antimony and arsenic in germanium, are termed "donor" impurities because they contribute to the conductivity of the basic material by donating electrons to an unfilled "conduction" energy band in the basic material. The donated negative electrons in such a case constitute the carriers of current and the material and its conductivity are said to be of the N-type. This is also known as conduction by the "excess process." Small amounts of other impurities, for example, boron in silicon and aluminum in germanium are termed "acceptor" impurities because they contribute to the conductivity by "accepting" electrons from the atoms of the basic material in the "filled band." Such an acceptance leaves a gap or "hole" in the "filled band." By interchange of the remaining elec-

trons in the "filled band," these positive "holes" effectively move about and constitute the carriers of current, and the material and its conductivity are said to be of the P-type. The term "defect process" may also be applied to this type of conduction. A further discussion of semiconductors of the type indicated may be found in the literature, for example "Crystal Rectifiers" by H. B. Torrey and C. A. Whitmer, volume 15 of the M. I. T. Radiation Laboratories Series.

Methods of preparing silicon of either conductivity type or a body of silicon including both types are known. Such methods are disclosed in the application of J. H. Scaff and H. C. Theuerer filed December 24, 1947, Serial No. 793,744 and United States Patents 2,402,661 and 2,402,662 to R. S. Ohl. Such materials are suitable for use in connection with the present invention. Germanium material may also be made in either conductivity type or in bodies containing both types and it may be so treated as to enable it to withstand high voltages in the reverse direction from the rectification viewpoint. This material may be prepared in accordance with the process disclosed in the application of J. H. Scaff and H. C. Theuerer filed December 29, 1945, Serial No. 638,351.

The term "barrier" or "electrical barrier" used in the description and discussion of devices in accordance with this invention, is applied to a high resistance interfacial condition between contacting semiconductors of respectively opposite conductivity type or between a semiconductor and a metallic conductor, whereby current passes with relative ease in one direction and with relative difficulty in the other.

The device shown in Fig. 1 comprises a symmetrical semiconductive disc 10 mounted in a cylindrical housing with conductors 11 and 12 making contact respectively to opposite faces of a thin portion of the disc. The disc 10, which may be of high back voltage germanium, or other suitable semiconductive material, may be made by cutting a circular piece about 0.125 inch in diameter from a thin slab of semiconductor (about .025 inch thick) with a hole saw and lapping a spherical depression in each face. A rugged symmetrical element having a thickness of a few mils (.002 to .004 inch) at its thinnest portion may thus be obtained.

The disc 10 may be seated in a counterbored portion of an internally threaded metal cylinder 14 which may be of brass, nickel, or like suitable material. A spring washer 15 backed by the threaded insulating member 16 may be used to hold the disc 10 in place. A similar insulating member 17 may be screwed into the opposite end of cylinder 14. The insulating members may be of a suitable ceramic or plastic material.

Terminal members 18 and 19, which may be secured by screw threads to the outer ends of insulating members 16 and 17, respectively, serve also as supports for studs 21 and 22, respectively. The studs are slidably fitted to the terminal members and may be secured in place by set-screws 23 and backed by set-screws 24. The terminal members, studs and set-screws may be of nickel, brass, or like suitable material.

The conductors 11 and 12 which may be S-shaped springs of phosphor bronze or like suitable material may be secured in axial bores in the ends of the studs as by solder.

After the parts are assembled with the conductors 11 and 12 out of contact with disc 10, the studs may be advanced until contact is made

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to substantially opposite points on opposed faces of the thin portion of the disc 10 and then secured in place by the set-screws 23. Determination of proper preliminary orientation of the contact may be made by visual inspection through suitable orifices (not shown). The correct final contact may be determined by connecting the device in a suitable circuit containing an indicator such as an oscilloscope and adjusting until the right electrical characteristics are obtained. This may be done, for example, by applying an alternating current voltage between the semiconductor and a contact and then advancing the contact until rectification is indicated on the oscilloscope. The contact holder may then be advanced slightly further say .003 inch to insure a stable contact.

In a device of the construction illustrated in Fig. 1 and above described, the contact 12 may be operated as the collector, the contact 11 as the emitter and cylinder 14 as the base electrode. In a typical case, the collector may be biased at of the order of 10-100 volts negative relative to the base electrode and the emitter biased at of the order of 0.1 to 1.0 volt positive with respect to the base electrode. With such construction, power gains of the order of 20 decibels have been obtained at audio and radio frequencies.

The device illustrated in Fig. 2 is in all respects except for the semiconductive member 30 like that shown in Fig. 1. The member 30 is dished on one side only and may be of a thickness to provide the desired few mils thickness at the thinnest section.

The modification shown in Fig. 3 in connection with a coaxial line and other circuit elements, differs from those previously described in having a complete metallic housing. The housing may be a metal cylinder 40 of nickel, brass, or the like, in which the other elements are mounted. In the use of illustrated, this housing provides a sleeve into which the coaxial line elements may be fitted. This configuration, however, is also useful in other situations than in connection with a coaxial line.

A symmetrical semiconductive disc 20, like the disc 10 of Fig. 1, is provided with a mounting ring 41 in which it may be secured by solder, cured metallic paste, or like material forming a conductive bond. Ring 41 is a push fit in cylinder 40 and is located centrally thereof. The contact members 42 and 43, which may be like those previously described, may be secured to the studs 44 and 45, respectively, in any suitable manner.

The studs 44 and 45 may be secured in insulating discs or cylinders 46 and 47, respectively. The insulating discs or cylinders, of a suitable ceramic or plastic material, are dimensioned to make a push fit within cylinder 40. With the semiconductive member 20 in place, the members 42 and 43 may be brought into suitable contact with substantially opposite points of opposed faces of the thin part of disc 20 in the manner previously described.

The translating device just described and as shown in Fig. 3 acts as an amplifier to compensate for the loss in a coaxial line represented by the equal sections 50 and 51 connected to opposite ends of the device.

In the example illustrated, the line is supposed to be 6.4 miles long and has a loss of about 40 decibels. The amplifier shown at the center of the line may be capable of 20 decibels gain and thus overcomes half of the loss, the remainder

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being made up by a second amplifier 52 at the end of the line.

With the input and output as indicated in Fig. 3, the emitter bias may be supplied to element 20 over one section of the line from source 53 and the collector voltage over the other section from source 54. The emitter and collector biases for the amplifier 52 are supplied by sources 55 and 56, respectively. The coupling transformers T are inserted where required.

The foregoing description of various modifications of this invention is for purpose of illustration only and is not intended to be taken as limiting the invention.

What is claimed is:

1. A translating device comprising a body of semiconductive material having a thin central portion and a thick portion surrounding said central portion, said body being symmetrical with respect to an axis and to a plane perpendicular to said axis, a conductive housing supporting the body centrally of its interior and in electrical connection therewith, and symmetrically related conductive means making rectifying contact to opposite sides of the thin central portion of the body substantially at the respective ends of said axis.

2. A circuit element comprising a disc of semiconductive material having a thin central portion defined by symmetrical depressions in opposite faces of the disc, means for making connection respectively to substantially opposite points on opposed faces of the thin portion of said disc, and means for making additional connection at the periphery of the disc.

3. A circuit element comprising a disc of semiconductive material of one conductivity type having a central portion of the order of a few mils in thickness and having also a peripheral portion substantially thicker than said central portion, colinear electrodes making rectifying contact respectively to opposite faces of said central portion, and a third electrode making contact to said peripheral portion.

4. A circuit element comprising a disc of semiconductive material having a very thin central zone and a relatively thick peripheral zone, a metallic cylinder in which said disc is mounted intermediate of the cylinder's ends, means for making electrical connection between the cylinder and the peripheral portion of the disc, means for making rectifying contact respectively with opposite faces of the disc within the central zone, and means for supporting the contact means in insulating relation to the cylinder.

5. A circuit element comprising a body of semiconductive material having opposed concave faces defining a thin central zone and a thicker peripheral zone, a conductive housing, means for mounting said body within the housing and in electrical connection therewith, means for making electrical connections respectively to opposite faces of the central zone, and means for supporting the connecting means in insulating relation to the housing.

6. A circuit element comprising a housing, a body of semiconductive materials mounted within and centrally of said housing, said body having a thick peripheral portion and a thin central portion, means including elements secured to said housing for making contact respectively to opposite faces of the thin portion of the body, and other means for making contact to the thick peripheral portion of the body.

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7. Translating means comprising a body of semiconductive material having a thin central portion and a thicker peripheral portion, means for making electrical connection respectively to opposite points on opposed faces of said thin portion, means for making electrical connection to the peripheral portion, and means including sources of electrical power for interconnecting said connecting means.

8. A circuit element comprising a body of semiconductive material having a thin central portion and a thicker peripheral portion, means for making electrical connections respectively to opposite points on opposed faces of said thin portion, and means for making electrical connection to the peripheral portion.

9. An amplifier comprising a circuit element including a body of semiconductive material, a conductive housing, means for mounting the body centrally of the housing and in electrical connection therewith, means in insulating relation to said housing, for making electrical connections respectively to opposite sides of said body, coaxial line sections fitted respectively to opposite ends of said housing on either side of the semiconductive body, and means for supplying current to the circuit element over each line section.

10. An amplifier comprising a circuit element including a disc of semiconductive material having a thin central portion, said disc being both radially and axially symmetrical, a conductive cylinder housing said disc midway between its ends and in electrical contact therewith, and symmetrically related conductive means making contact to opposite sides of the thin portion of the disc substantially at the respective ends of its axis, coaxial line sections fitted respectively to opposite ends of said housing and to the symmetrical contacts, and means for supplying current to the circuit element over each line section.

11. A circuit element for inclusion in a coaxial line comprising a cylindrical conductive housing, a radially and axially symmetrical semiconductive disc of one conductivity type having a thin central portion and mounted in conductive relation to and within the conductive housing midway between its ends, a pair of conductors mounted on opposite sides of the disc, in insulating relation to the conductive housing and axially thereof, and like contact means mounted respectively on the axial conductors and making colinear contact to opposite faces of said disc.

12. An amplifier comprising a body of semiconductive material having a thin central portion and a thicker peripheral portion, means for making electrical connection respectively to opposite points on opposed faces of said thin portion, means for making electrical connection to the peripheral portion, an input circuit including means for applying a relatively low voltage between one opposed connection and the peripheral connection and an output circuit including means for applying a relatively high voltage between the other opposed connection and the peripheral connection.

13. A translating device comprising a body of semiconductive material having a thin central portion and a thicker peripheral portion, means for making rectifying connection respectively to opposite points of opposed faces of the thin portion of the body, and means for making substantially ohmic connection to the peripheral portion of the body.

14. A translating device comprising a disc of high-back-voltage germanium rectifier material

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of one conductivity type having a thin central portion and a thicker peripheral portion, means for making rectifying contact respectively to opposite points of opposed faces of the thin portion of the disc, and means for making substantially ohmic connection to the edge of the disc.

15. An electrical translating device comprising a slab of semiconductive material having a dished portion in one face thereof, a first contact engaging the surface of said dished portion and defining a rectifying junction therewith, a second contact engaging the other face of said slab and defining a rectifying junction therewith, and means comprising a substantially ohmic connection to said slab at a region spaced from said first and second contacts for controlling the impedance of the current path through said body between said first and second contacts.

16. An electrical translating device comprising a slab of semiconductive material having opposed dished portions in opposite faces thereof, a first contact to one of said faces at a point in the dished portion thereof, a second contact to the other of said faces at a point in the dished portion thereof, and a base connection to said slab at a region spaced from said first and second contacts.

17. An electrical translating device comprising a slab of semiconductive material having aligned dished portions in opposite faces thereof, aligned contacts engaging said faces within the dished portions thereof, and means for establishing electrical connection to said slab at a region spaced from said contacts.

18. An electrical translating device comprising a slab of semiconductive material having a dished portion in one face thereof, a first contact engaging said one face within said dished portion thereof, a second contact substantially colinear with said first contact and engaging the opposite face of said slab, and a connection to said slab coaxial with said first and second contacts.

19. An amplifier comprising a circular disc of semiconductive material having central, substantially identical axially aligned recesses in opposite faces thereof, a pair of substantially colinear point contacts engaging said faces at the axis common to said recesses, and a cylindrical contact coaxial with said point contacts and connected to the periphery of said disc.

20. A coaxial line comprising inner and outer conductors, and a disc of semiconductive material of one conductivity type within the outer conductor and having its periphery electrically connected thereto, said disc having a central portion opposite faces of which are between and engaged by juxtaposed points of said inner conductor.

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