ASYMMETRIC ELECTRICAL CONDUCTING DEVICE

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FIG. 1

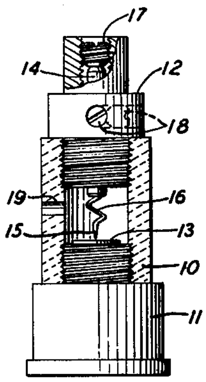


FIG. 3

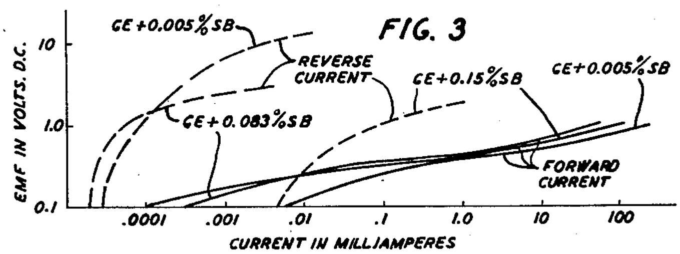


FIG. 2

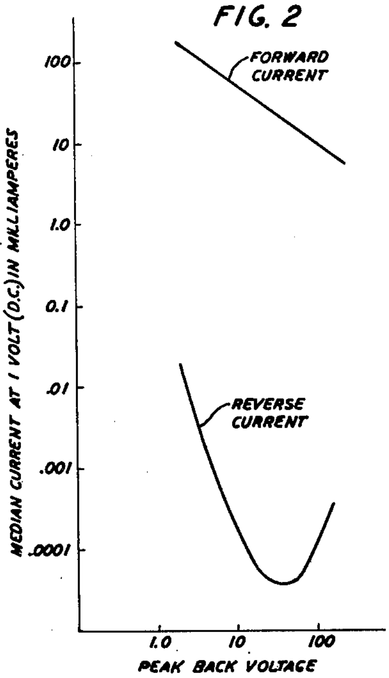
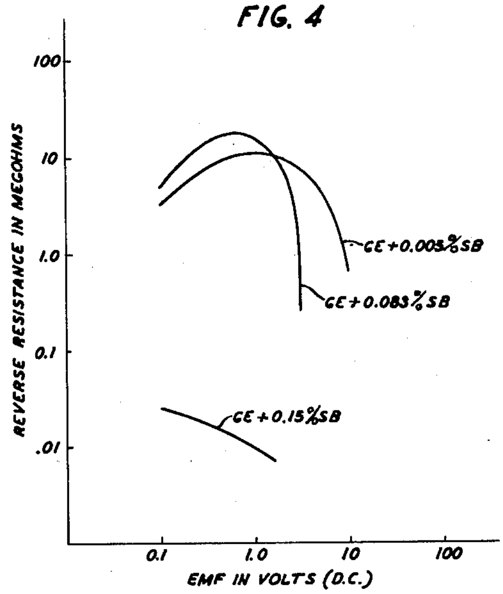


FIG. 4



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ASYMMETRIC ELECTRICAL CONDUCTING DEVICE

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6 Claims. (Cl. 175—366)

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This invention relates to asymmetric electric conducting or translating devices and more particularly to point contact rectifiers or detectors of the type, such as disclosed in the applications Serial No. 638,351, filed December 29, 1945, of Jack H. Scaff and Henry C. Theuerer and Serial No. 22,627, filed April 2, 1948, of Karl M. Olsen.

One object of this invention is to improve the operating characteristics of asymmetric conducting devices of the type including a crystal or slab of germanium alloy.

More specifically, objects of this invention are to increase the rectification ratio for such devices, to obtain high reverse resistances therefor, to increase the forward current in a germanium type rectifier or detector and to achieve nonlinearity of forward current characteristic over a range of voltages for germanium type detectors.

It has been discovered that the operating characteristics of point contact germanium alloy detectors or rectifiers are dependent to a large extent upon the rectifying junction produced between the contact point and the slab or crystal and that exceptionally advantageous characteristics are obtainable by the use of a contact point of a silver alloy. For example, in illustrative devices, rectification ratios of the order of one million at one volt direct current and reverse resistances of the order of 20 megohms and higher at one volt direct current have been obtained.

It has been discovered also that with point contact rectifiers including a slab or crystal of germanium containing a fraction of a per cent of antimony, definite correlations obtain between the electrical properties of the device and the antimony content and that unusually advantageous properties are realized with slabs or crystals produced from ingots of germanium-antimony alloy in which the antimony constitutes between about 0.005 and 0.15 per cent by weight of the total.

This invention will be more clearly and fully understood from the following detailed description when read with reference to the accompanying drawings in which:

Fig. 1 is an elevational view, partially in section, of a germanium type rectifier illustrative of one embodiment of this invention;

Fig. 2 is a graph illustrating the relationship between the current and peak back voltage (as determined by a tungsten probe test) of the germanium-antimony materials employed in the preparation of these devices.

Fig. 3 is a graph showing current-voltage characteristics of several devices representative of this

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invention including slabs cut from germanium-antimony alloys of various antimony contents; and

Fig. 4 is a graph showing typical reverse resistance characteristics for devices including slabs having current voltage properties of the form shown in Fig. 3.

Referring now to the drawings, the asymmetric conducting device or translator illustrated in Fig. 1, comprises a cylindrical insulating shell 10 internally threaded at opposite ends, and electrically conductive, threaded terminal plugs 11 and 12 screwed into the ends of the shell 10. Seated upon the inner end of the plug 11 is a circular slab or disc 13 of germanium alloy, which may be fabricated as described hereinafter. A stem 14 extends into the terminal plug 12 and carries a contact point 15 which has a spring section 16 therein. The point bears against the slab or disc 13, the bearing pressure of the point upon the disc being determined by a set screw 17 threaded into the plug 12 and abutting the stem 14. The latter may be locked firmly in place to prevent alteration in the contact point to disc pressure by set screws 18.

After the device has been assembled, the contact spring or point is brought into contact with the slab or disc and then is advanced a preassigned distance to obtain the desired contact point pressure. The device is tapped lightly on the side to minimize the reverse current. Then a direct current of the order of 200 to 300 milliamperes is passed through the unit in the forward direction for a period of the order of 15 seconds. This electrical treatment markedly increases the one volt direct current, forward current of the unit without deleteriously effecting the reverse current. Also it stabilizes the electrical characteristics of the device. Finally, the device may be vacuum impregnated with a suitable wax which may be introduced into the shell by way of an opening 19 therein.

The slab or crystal may be fabricated in the manner described in the Scaff and Theuerer application heretofore identified. Briefly, in this method a body of germanium, produced for example, by reduction of germanium dioxide, is broken into small pieces which are placed in a crucible together with a prescribed amount of an impurity, such as antimony. The charge is melted and the mass is cooled progressively from one end to the other to effect a gradual distribution of the impurity through the mass, the greatest concentration of the impurity being at the end of the mass last to cool. In ingots made as described in the above-identified application wherein the heating is effected by an induction coil encircling the crucible, the cooling may be accomplished by raising the coil at the rate of one-eighth of an inch per minute while maintaining the power input to the coil constant. Suitable slabs are then obtained from the mass by cutting the latter in planes normal to its ends. If the impurity is such as to result in n-type alloy throughout the mass, the slabs may be used directly. If, however, the impurity is such that p-type material results, the mass or the slabs may be heat treated to convert the material to n-type. The face of the slabs to which the point contact is to be made is lapped with a fine abrasive and then etched to produce a very smooth surface.

Silver alloy point contacts have been found to produce exceptionally satisfactory rectifying junctions with crystals composed predominantly of germanium. Impregnated units having contact points 15 produced by shearing the tips of 0.005 inch diameter wire at 45 degrees to the length and bringing said points to bear with a pressure of approximately 5 to 15 grams upon the surface of an n-type germanium slab having 0.005 per cent antimony added and cut from a portion of the ingots having a peak back voltage of 20 volts, as determined by tungsten contact probe tests, have been found to have forward current I_F, and a reverse current I_R, and a rectification ratio R at one volt direct current as given below for the various silver alloys indicated. For comparison purposes, data for a similar unit including a tungsten contact point is given. The currents are given in milliamperes.

Material	I_F	I_R	R
Tungsten	12	.049	245
Silver	25	.00007	340,000
95% silver-5% tin	33	.00003	1,100,000
95% silver-5% palladium	34	.00005	680,000
90% silver-10% gold	34	.00006	570,000
90% silver-10% copper	45	.00003	1,500,000

It is evident from the above table, that silver and silver alloy contact points produce at least a thousand fold increase in rectification ratio over the tungsten points commonly used heretofore.

The exceptionally high ratios appear to be independent of the exact form of the contact point. Comparable results would be obtained by using conical silver or silver alloy contact points in place of the sheared contact points described above.

As indicated heretofore, the rectifying and non-linear characteristics of a point contact germanium crystal asymmetric conductor are dependent not only upon the point contact but also on the added impurity content of the ingot and the location of the cut of the crystal from the particular germanium ingot. When an ingot is prepared as described, the progressive cooling effects a gradual distribution of the impurity throughout the mass, the greatest concentration of the impurity occurring at the top. As a result of this variation of antimony content throughout the ingot, the asymmetric conducting characteristics of crystals cut from the ingot vary in accordance with the location of their cut. The impurity distribution is indicated qualitatively by the peak back voltage of the crystal material as determined by tungsten point probe test taken over longitudinal sections of the

ingot. It has been found that the peak back voltage decreases with increased antimony content in a germanium antimony crystal, hence the peak back voltage of a longitudinal section of the ingot decreases from the bottom to the top. For a more complete explanation of these physical relationships, reference is made to my copending application Serial No. 22,627 referred to above.

The general characteristics, i. e. the forward and reverse currents, of a unit can be directly correlated with the peak back voltage of the slab used. This has been indicated by the graph of Fig. 2 wherein the forward and reverse currents at one volt direct current has been plotted against the peak back voltage, as determined by a tungsten point probe test, for germanium-antimony crystals having 95 per cent silver, 5 per cent tin point contacts. It is to be noted that higher forward currents are associated with lower peak back voltage compositions and minimum reverse currents are obtained from compositions having peak back voltages of the order of 30 volts say between 20 and 50 volts.

The curves of Figs. 3 and 4 illustrate the direct current characteristics of rectifier units of the construction illustrated in Fig. 1, and show the variations which result from changes in the amount of antimony which was added to the ingot when it was originally formed. While these properties will vary depending upon the location of the cut in the ingot and the alloy employed in the point contact, in order to disclose representative results, the curves of Figs. 3 and 4 have been made from data obtained from tests of units employing 95 per cent silver, 5 per cent tin contact points and crystals cut normal to the axis of the ingot and from its central portion.

The logarithmic plots of voltage against current shown in Fig. 3 illustrate the non-linearity of the forward current which is attained with units constructed in accordance with this invention. The forward current characteristics over a limited voltage range approximately follows the equation $I=E^x$. Hence the degree of non-linearity of these characteristics at a given voltage is expressed numerically by the value x which is the reciprocal of the slope for the characteristic (log voltage v. log current) at that voltage. The smallest slope of the curves occurs for voltages between 0.3 and 0.5 volt. In this voltage range the value of the exponent x is about 8 for units made from ingots in which the added antimony is between 0.005 and 0.083 per cent.

Fig. 4 illustrates the reverse resistance-voltage relation in rectifiers having the characteristics shown in Fig. 3. To be noted especially in Fig. 4 are the very large values of reverse resistance obtainable. For example, a typical rectifier unit including a slab or crystal cut from an ingot comprising 0.005 per cent added antimony and having a peak back voltage of 35 volts has a reverse resistance of about 12 megohms at one volt and a forward resistance of about 30 ohms, the rectification ratio being on the order of 400,000. The .083 per cent added antimony ingot having a peak back voltage of 10 volts as determined by the tungsten probe test showed even better properties at one volt of direct current, the reverse resistance being 16 megohms and the forward resistance 13 ohms to indicate a rectification ratio of 1.2×10^6. An example of a rectifier cut from a germanium antimony crystal having .15 per cent added antimony and a peak back voltage of 2 volts is disclosed on the lowest curve in Fig. 4. This unit while having a low rectification ratio compared to the others disclosed, the reverse resistance being about 10,000 ohms at one volt direct current, may be advantageously used in applications where high forward currents are required since its forward resistance is only 6 ohms at one volt and as a result the unit passes a forward current of over 160 milliamperes at that voltage.

In summarizing, it has been found that units made up from crystals or slabs cut from properly prepared germanium-antimony ingots, containing a small fraction of 1 per cent of antimony having an electrode engage one face and a point contact of silver or a silver alloy engage the other face, produce very high rectification ratios which are determined by the antimony content of the crystal and the composition of the silver alloy of the point contact. The antimony content bears a direct relationship to the peak back voltage of the crystal material and this back voltage in turn can be correlated with the forward and reverse currents of crystal rectifiers having any particular type of point contact to predict the characteristics of a unit. Some of the more useful relationships which have been determined include the findings that as the antimony concentration increases, the peak reverse voltage which the rectifier will stand without deterioration decreases; an increase of the antimony content increases the forward current at one volt direct current; the reverse current at one volt direct current decreases with increasing antimony content to a minimum value and then increases again with further increase in antimony, the minimum point occurring in the range between 20 and 50 volts direct current as measured by the tungsten probe test; and the higher the antimony content, the lower the voltage at which the maximum reverse resistance occurs.

While the curves of Figs. 2, 3 and 4 were obtained from tests of units employing 5 per cent tin, 95 per cent silver contact points, it is to be understood that these curves are only illustrative and are not to be interpreted in a limiting sense there being a multitude of silver alloy contact points which produce similar results as evidenced for example by the alloys containing palladium, gold and copper disclosed heretofore.

What is claimed is:

1. An asymmetric electrical conducting device, comprising a slab of germanium having about 0.005 per cent antimony alloyed therewith, and a silver alloy contact point containing a substantial proportion of silver ranging up to about 95

per cent of the total bearing against one face of said slab.

2. An asymmetric electrical conducting device, comprising a slab predominantly of germanium, and a silver-tin alloy contact point containing a substantial proportion of silver and at least 5 per cent of other metals bearing against one face of said slab.

3. An asymmetric electrical conducting device, comprising a slab predominantly of germanium, and a silver-palladium alloy contact point containing a substantial proportion of silver and at least 5 per cent of other metals bearing against one face of said slab.

4. An asymmetric electrical conducting device, comprising a slab of germanium-antimony alloy in which the antimony constitutes but a small fraction of one per cent by weight of the total, an electrical connection to one face of said slab, and a silver-tin alloy point contact bearing against the opposite face of said slab, said point alloy containing about 95 per cent silver and about 5 per cent tin.

5. An asymmetric electrical conducting device, comprising a slab of germanium-antimony alloy in which the antimony constitutes but a small fraction of one per cent by weight of the total, an electrical connection to one face of said slab, and a silver-palladium point contact bearing against the opposite face of said slab, said point alloy containing about 95 per cent silver and about 5 per cent palladium.

6. An asymmetric electrical conducting device, comprising a slab of germanium-antimony alloy in which the antimony constitutes but a small fraction of one per cent by weight of the total, an electrical connection to one face of said slab, and a 90 per cent silver, 10 per cent gold alloy point contact bearing against the opposite face of said slab.

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