Sept. 7, 1943. W. C. ELLIS ET AL 2,329,038

RESISTOR

Filed July 8, 1942

FIG. 1

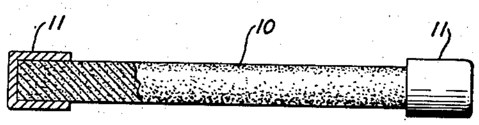



FIG. 2

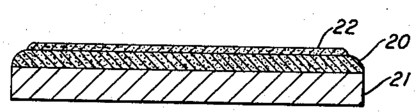
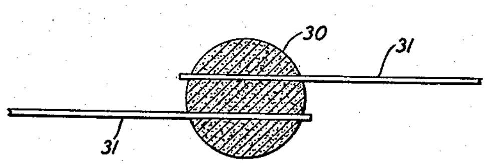



FIG. 3

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# UNITED STATES PATENT OFFICE

2,329,038

## RESISTOR

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9 Claims. (Cl. 201—76)

This invention relates to resistors and to means and methods for controlling the resistance characteristics thereof. More particularly it relates to resistors made of alloys of tellurium and selenium with or without the addition of tin, bismuth or sulphur.

Both tellurium and selenium have relatively high resistivities at normal temperatures being generally classified in the group of materials known as semiconductors. The resistivity of selenium depends upon its allotropic form, method of preparation and the treatment thereof. Selenium in its amorphous state has such a high resistivity that it may be classified as an insulator, but the crystalline modification although high in resistivity is considered to be a semiconductor. In any case, selenium has in general a higher resistivity than tellurium. If selenium be added to tellurium the resulting alloy has a higher resistivity than tellurium alone and the resistivity is higher for large additions of selenium than for small. The addition of other materials to a tellurium-selenium combination may raise or lower the resistivity depending upon the characteristics of the added material. Small amounts of tin or bismuth, for example, reduce the resistivity of a mixture of equal proportions of tellurium and selenium. On the other hand, small additions of sulphur to such a tellurium-selenium mixture raise the resistivity thereof.

It is an object of this invention to so proportion the amount of tellurium and selenium or of tellurium, selenium and tin, bismuth or sulphur in a resistance alloy, as to obtain not only certain resistivity values but also desired values of resistance-temperature coefficient.

One feature of this invention is a tellurium-selenium alloy having a resistance-temperature coefficient that is substantially zero over the range 0° to 100° C.

Another feature of this invention is a tellurium-selenium-sulphur alloy having a resistance-temperature coefficient of very high absolute value.

A further feature of this invention is an alloy of tellurium, selenium and tin in which the presence of a small amount of tin not only lowers the resistivity but raises the absolute value of the resistance-temperature coefficient.

Other and further objects and features of this invention will be more clearly and fully understood from the following detailed description thereof taken in connection with the appended drawing in which:

Fig. 1 shows a stick or rod resistor, which is one of the forms in which applicants' resistance material may be used;

Fig. 2 shows a specialized type of resistor, i. e., a so-called dry rectifier in which the resistance materials of this invention may also be used; and

Fig. 3 shows a bead resistor, which form may be employed for resistors having a resistance-temperature coefficient of high absolute value such as thermistors.

The material employed in making the resistors of this invention may be prepared by melting together the desired proportions of ingredients and forming them into a resistor body of suitable shape and size.

One common form of resistor is the rod or stick illustrated in Fig. 1 in which **10** is the body of resistance material and **11** are the terminals. This form of resistor may be made by casting the molten resistance material in a mold to form the stick **10**. The terminals, which may be caps **11** of metal, as illustrated, may be secured to the ends of the stick **10** in any suitable manner. For example, the terminals may be attached by some modification of the welding technique or by a cement of proper conductive value.

The resistance material may be incorporated in a resistor device of the type more commonly known as a dry rectifier. One form of such device is illustrated in Fig. 2. The resistance material **20**, which is usually in a relatively thin layer, is provided with a backing or supporting electrode **21**. The member **21** may be of a suitable metal, such as nickel or iron. Contact is made to the front of the resistance layer **20** by means of another metallic electrode **22**. The resistance material **20** in a molten state may be spread on the electrode **21**. The front electrode **22** may comprise a relatively soft metal, such as tin or a tin-bismuth-cadmium alloy. This electrode may be applied by spray-depositing the metallic material on the surface of the resistance material.

Another form which the resistor may take is that illustrated in Fig. 3. The body **30** of resistance material, which may be of approximately spherical, ovate or other suitable configuration, may have the electrodes or leads **31** embedded therein. This form of resistor may be made by applying a small bead of molten resistance material to the leads **31**, while said leads are held in spaced, substantially parallel relation by a suitable fixture. This type of resistor is particularly suitable where a very small volume of resistance material is desired.

Any of the various modifications of the resistor material of this invention may be used in any of the illustrated forms of resistor or in other suitable forms, although some of the modifications may be particularly suitable for certain special types of resistors.

For purpose of discussion tellurium may be considered as the basic material although in some modifications, selenium appears in equal or greater amounts than tellurium. The resistance-temperature coefficient of tellurium is negative and has an absolute value in the order of $3 \times 10^{-3}$ between 0° and 100° C. and a specific resistance at 0° C. in the order of $1.7 \times 10^{0}$ ohm centimeters. Both the resistance-temperature coefficient and the resistivity of selenium are higher than for tellurium. When selenium is added to tellurium, the resistivity is increased, however, as the amount of selenium is increased the absolute value of the resistance-temperature coefficient decreases until at approximately 75 per cent tellurium and 25 per cent selenium it is zero. Upon addition of more selenium the absolute value of the coefficient increases but remains negative and the resistivity is increased.

If a third material is added to a composition containing approximately equal proportions of tellurium and selenium, marked changes in both resistivity and resistance-temperature coefficient may be made. In a composition containing, for example, 45 per cent each of selenium and tellurium and 10 per cent sulphur, the resistivity is increased about a thousandfold and the resistance-temperature coefficient is increased greatly in absolute value with respect to a material containing equal portions of tellurium and selenium. The change of resistance with temperature in this material is so great that it is useful in that type of resistor designated as a thermistor.

The addition of about 5 per cent of tin to a mixture of equal proportions of tellurium and selenium decreases the resistivity considerably and at the same time raises the absolute value of the resistance-temperature coefficient. On the other hand if about 10 per cent bismuth is added to the selenium-tellurium composition instead of the tin, the resistivity is reduced several thousandfold with an accompanying reduction in absolute value of the resistance-temperature coefficient. Thus it is possible by varying the relative amounts of tellurium and selenium or by the addition of small amounts of other material thereto to obtain a series of resistors having a wide range of both resistivity and resistance-temperature coefficient.

It has been found that the stability of the various compositions may be greatly increased by suitable heat treatment. For example, when resistors of the various compositions previously noted were heated at about 200° C. for fifty hours, stability was achieved to a great extent.

Although the invention has been disclosed with reference to several specific embodiments thereof, it will be understood that it is not restricted thereto but is limited in scope by the appended claims only.

What is claimed is:

1. A resistor comprising a composition of metallic elements consisting of from 40 to 85 per cent tellurium and a remainder including from 15 to 25 per cent selenium.

2. A resistor comprising a compostion of metallic elements consisting of tellurium in excess of 50 per cent and a remainder including from 15 to 25 per cent selenium.

3. A resistor comprising a composition of metallic elements consisting of tellurium to the extent of slightly less than 50 per cent and a remainder including selenium, the amount of selenium being approximately the same as that of tellurium.

4. A resistor comprising a composition of metallic elements consisting of tellurium, selenium and sulphur, the tellurium and selenium being in approximately equal proportions and the sulphur not exceeding about 10 per cent.

5. A resistor comprising a composition of metallic elements consisting of tellurium, selenium and tin, the tellurium and selenium being in approximately equal proportions and the tin not exceeding about 10 per cent.

6. A resistor comprising a composition of metallic elements consisting of from 75 to 85 per cent tellurium and 25 to 15 per cent selenium.

7. A resistor comprising a composition of metallic elements consisting of 45 per cent tellurium, 45 per cent selenium, and 10 per cent sulphur.

8. A resistor comprising a composition of metallic elements consisting of 47.5 per cent tellurium, 47.5 per cent selenium, and 5 per cent tin.

9. A resistor comprising a composition of metallic elements consisting of 75 per cent tellurium and 25 per cent selenium.

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