

Dec. 5, 1967

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METAL FILM RESISTOR FOR LOW RANGE AND LINEAR
TEMPERATURE COEFFICIENT
Filed April 13, 1964

3,356,982

FIG. 1

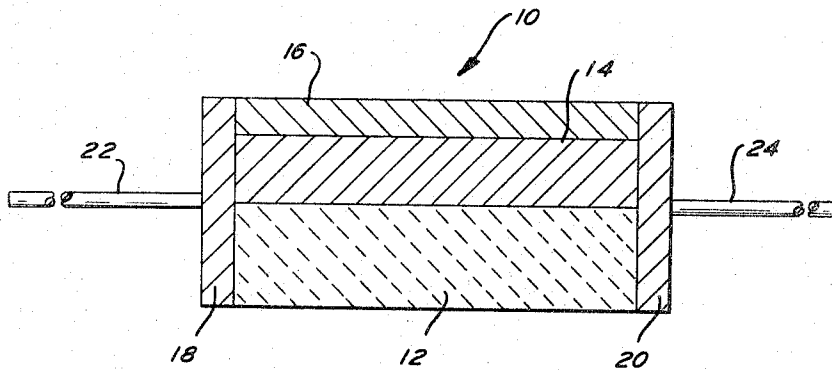


FIG. 2

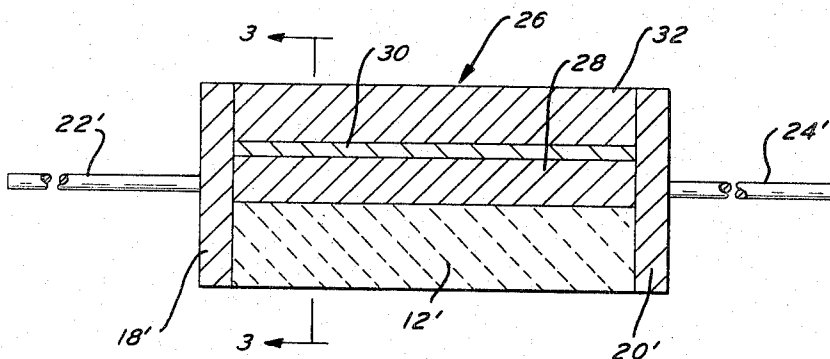
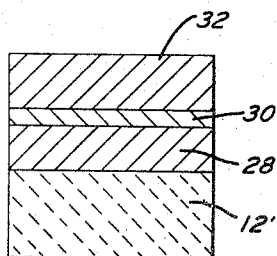


FIG. 3



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METAL FILM RESISTOR FOR LOW RANGE AND LINEAR TEMPERATURE COEFFICIENT

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Filed Apr. 13, 1964, Ser. No. 359,081

4 Claims. (Cl. 338—308)

This invention relates to a resistor having a low temperature coefficient of resistance and linear temperature versus resistance characteristics. More particularly, this invention relates to an evaporated metal film resistor with a low temperature coefficient of resistance that remains constant over a broad range of temperatures, and a method of making the same.

Current technology has produced a demand for resistors with temperature coefficients of resistance that are low in value and remain constant over a broad range of temperatures. Further, it is desirable that such resistors be more stable; that is, they should maintain a substantially constant resistance despite changes in temperature, humidity, and the load applied. Two areas of application for resistors are in measurement standards and space technology.

Metal film resistors have been made with the above set forth characteristics over limited ranges of temperatures. Resistors in the lower range of resistance (1 to 100 ohms/square), however, still exhibit pronounced variation in temperature coefficient. For example, military specifications for metal film resistances in the high ranges have been set at approximately ± 25 parts per million per centigrade degree change in temperature, whereas in the lower resistance ranges specifications have to be loosened to ± 50 p.p.m./° C. to ± 100 p.p.m./° C.

The alloy of gold-chromium when properly processed is known to exhibit the desired characteristics of low and linear temperature coefficient of resistance, together with good stability in low resistance range. However, resistors made from gold-chromium alloys have successfully been made only in wire form. As such, the high cost of material makes them too expensive to be commercially successful. Heretofore, when metal film resistors, which use less material and therefore are less expensive, have been made using a film of gold-chromium alloy they have exhibited a high temperature coefficient of resistance as compared to the low coefficient exhibited by the wire form of resistor.

It is therefore an object of this invention to provide a novel resistor that combines the best attributes of a metal film resistor with the better characteristics of gold-chromium resistance alloys.

It is another object of this invention to provide a novel resistor having a low temperature coefficient of resistance and which is stable under operating conditions.

It is still another object of this invention to provide a novel low ohmic range resistor having a controllable temperature coefficient of resistance and which is stable under operating conditions.

It is yet another object of this invention to provide a method of making a metal film resistor having good stability and low temperature coefficient resistance.

It is still a further object of this invention to provide a resistance having a low temperature coefficient of resistance and stability that is easily and relatively inexpensively produced.

Other objects will appear hereinafter.

For the purpose of illustrating the invention there is shown in the drawings forms which are presently preferred; it being understood, however, that this invention is not limited to the precise arrangements and instrumentalities shown.

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FIGURE 1 is a cross-sectional view of the resistor according to this invention.

FIGURE 2 is a cross-sectional view of another form of the resistor in accordance with this invention.

FIGURE 3 is a transverse section of embodiment shown in FIGURE 3, along the line 3—3.

As is known, the resistivity (ρ) of a resistor is not a linear function of temperature, except perhaps in limited ranges of temperature and for particular materials. Rather, resistivity is a function of an constant α (known as the temperature coefficient of resistance) times temperature in degrees centigrade plus another constant β (known as bend) times temperature raised to the second power in degrees centigrade. Obviously, if constants α and β can be made low in value or reduced to zero the resistivity of a resistor will be substantially independent of temperature.

When properly compounded and heat treated the alloy of gold-chromium is characterized by a small α and β . The bend or β is made small by adding the correct proportion of chromium to gold (97.5–98.4% gold, 1.6–2.5% chromium). The value of α is made small by heat treating the gold-chromium alloy. Small means a value that is close to zero.

When metal film resistors have been made using a gold-chromium alloy evaporated onto a non-conductive substrate such as glass or ceramic they have exhibited an α of about $+100$ p.p.m./° C. which is similar to the temperature coefficient of resistance of a wire resistor before heat treatment. However, upon application of the heat treatment to the thin film resistor, the α has become more highly positive rather than falling off toward zero as does the wire resistor. For this reason evaporated gold-chromium alloy resistors have not heretofore been successfully made.

It has been found that this unusual behavior in metal film resistors is due to the oxidation of a small amount of chromium in the metal alloy film. It has also been found that the metal alloy can be protected from oxidation by coating it with a thin film of chromium.

Referring now to the drawing in detail, wherein like numerals indicate like elements, there is shown in FIGURE 1 a resistor designated generally as 10.

The resistor 10 comprises a base 12 upon which a resistance material 14 is placed. A cover material 16 is placed over the resistance material 14. End terminals 18 and 20 are attached to the ends of the resistor so as to provide electrical contact between said resistor and the leads 22 and 24.

The resistance material 14 is a thin film of a gold-chromium alloy that has been placed on the base 12. The base 12 is made of a ceramic or glass and acts as a substrate upon which the resistance material 14 can be evaporated or otherwise placed thereon. The composition of the gold-chromium alloy is approximately 98% gold and 2% chromium by weight, whereas its thickness and length will depend on the ohmic value of the resistor. The cover material is chromium with a thickness that is approximately 10% the thickness of the gold-chromium alloy. In general, the overall thickness of the resistance material 14 and cover material 16 will be about 200 to 500 angstrom units.

The resistance material 14 and cover material 16 may be placed upon the substrate by any known coating process. However, it is preferable to use an evaporation technique, for the reason that it permits accurate control of the film being coated. The apparatus by which the alloy film is first evaporated onto the base and then the chromium film evaporated onto the alloy film are known and need not be described in detail.

After the coating process has been completed, the resistor is subjected to heat treatment by placing it in an

apparatus adapted for this purpose. It has been found that α can be made close to zero by an application of heat to the resistor for a period of four hours at a temperature of 325° C. The value of α can be varied (even made negative) by varying the length of time heat is applied.

Referring now to FIGURE 2, wherein elements similar to those shown in FIGURE 1 have been given prime numbers, there is shown a resistor 26 representing a second embodiment of this invention.

The resistor 26 comprises a base 12' upon which a layer of gold 28 is evaporated or otherwise placed, a thin layer of chromium 30 is placed over the layer of gold 28, and then a layer of gold 32 is placed over the middle chromium layer 30. Thus the resistor 26 comprises a layer of chromium sandwiched between two layers of gold. End terminals 18' and 20' are attached to the ends of resistor 26 so as to provide electrical contact between it and leads 22' and 24'. There is sufficient diffusion at the interfaces between the gold and chromium layers to provide the gold-chromium alloy, and therefore a resistor with the proper resistance-temperature characteristics. A resistor made according to the embodiment in FIGURE 2 is ideally suited for infinite resolution potentiometers.

Further variations are possible, such as evaporating chromium first, then gold alloy, or evaporating both simultaneously, or evaporating pure gold and chromium as above and heat treating to obtain the desired alloy. In the latter case, an excess of chromium is evaporated to allow for oxidation.

The terminals 18, 18' and 20, 20' are made by firing gold on the ends of the base 12 or 12' then attaching leads to the gold. An alternate means (not shown) would be to provide the terminals by evaporating gold bands on top of the chromium layer 16 in FIGURE 1.

It can thus be seen that a metal film resistor with a low temperature coefficient of resistance and good stability (for direct current as well as high frequency operation) has been described. The resistor will exhibit the above described characteristics in both low range (1-100 Ω /square) and the high range of resistance, which heretofore has not been possible with evaporated film resistors. It will also be noted that the resistor made according to the above set forth disclosure combines the excellent properties of gold-chromium wire resistors with the much lower cost of evaporated film resistors, making mass production possible. Over one thousand resistors of the one-quarter watt size can be made with three grams of alloy.

The shape of the resistors shown in the drawing represents only one form of the resistor, chosen so as to clearly and concisely describe the invention. It is to be understood that the shape of the resistors is not limited to that shown in the drawing. In addition to the illustrated rectangular shape, the resistors can be made in the more conventional cylindrical shape. In that case, the resistors would consist of an inner cylindrical core of non-conductive material and outer metallic coating applied in accordance with the disclosure.

The present invention may be embodied in other specific

forms without departing from the spirit or essential attributes thereof and, accordingly, reference should be made to the appended claims, rather than to the foregoing specification as indicating the scope of the invention.

I claim:

1. A highly stable metal film electrical resistor having a low temperature coefficient of resistance comprising a base of non-conductive material, a film of resistance material having a low temperature coefficient of resistance consisting of an alloy of 98% gold and 2% chromium vacuum evaporated onto said base, a thin film of cover material consisting of chromium vacuum evaporated onto said resistance material to a thickness of approximately 10% of the resistance material, and a pair of gold terminals in electrical contact with said resistance material.

2. An electrical resistor in accordance with claim 1 wherein said terminals comprise gold bands vacuum evaporated onto said chromium layer.

3. A metal film electrical resistor comprising a base of electrical insulating material, a film of gold-chromium alloy resistance material on said base, said alloy including from about 97.6% to about 98.4% gold by weight of alloy and from about 1.6% to about 2.4% chromium by weight of alloy; and a thin metal film consisting essentially of chromium metal vacuum deposited on said alloy resistance material.

4. A metal film electrical resistor having a resistance of 1 to 100 ohms/square and a low temperature coefficient of resistance comprising a substrate of electrically insulating material, a film of electrical resistance material consisting of gold-chromium metal alloy vacuum evaporated onto said substrate and including from 76.5% to 98.4% gold and 1.6% to 2.4% chromium by weight of alloy, and a cover material consisting of chromium metal vacuum evaporated onto said film of electrical resistance material.

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