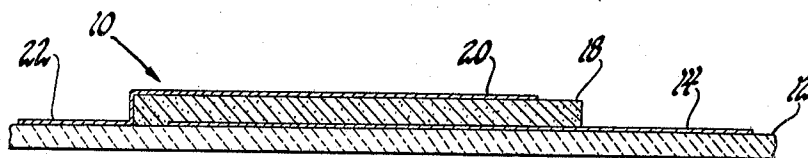
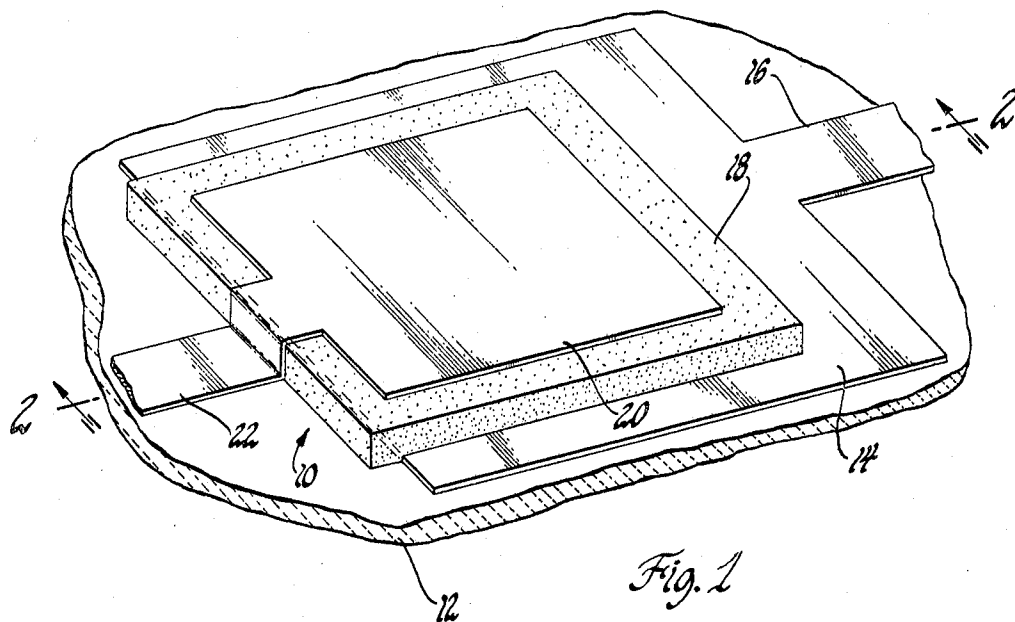


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THERMISTOR CONSTRUCTION

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2 Claims

ABSTRACT OF THE DISCLOSURE

A relatively low resistance printed thermistor assembly having a thermistor film sandwiched between a lower and an upper conductive film which serve as terminals is disclosed. This thermistor assembly is supported by an insulative substrate. A specific example is a sheet of alumina substrate which has a conductive film of palladium-silver printed thereon. Printed on top of the palladium-silver film is a thermistor film containing cobalt oxide, manganese oxide and glass. A second palladium-silver conductive film is printed on top of the cobalt oxide-manganese oxide thermistor film.

This invention relates to thermistors, and more particularly to a printed low resistance thermistor assembly.

Thermistors are defined as being electrical resistors made of a material whose resistance varies sharply in a known manner with the temperature, that is, they have a medium to high temperature coefficient of resistance. Thermistors are formed from copper oxide, manganese oxide, iron oxide, chromium oxide, cobalt oxide and nickel oxide. The resistivity of these metal oxides separately or individually is high and as a result, mixtures of two or more of these oxides are usually used to obtain a thermistor composition having a lower resistivity.

The most widely used thermistors are discreet ceramic-like beads, rods and discs which have two terminals connected thereto. Thermistors of this type are suitable for use in many applications and are frequently used in highly sensitive thermostats and automatic controls. In certain applications such as in the temperature sensing element of a hybrid integrated voltage regulator, it is desirable because of manufacturing economies to use a low resistance thermistor in a form other than a bead, rod, or disc, for example a printed thermistor, which is more compatible with the manufacturing processes used to form the electrical circuitry which is connected to the thermistor.

The use of printed thermistor films on ceramic substrates to form low resistance thermistors have heretofore not been feasible due to the high resistivity of the thermistor material. A conventional strip of a printed resistor film (1 to 2 mils thick) 100 mils wide by 200 mils long terminating at each end of the resistor strip with a conductive material would have a resistance which can be varied from as low as 10 ohms up to 10,000 ohms or more at 25° C. depending upon the resistance desired. Thermistors, however, have such a high resistivity that a conventional strip of printed thermistor film (1 to 2 mils thick) 100 mils wide by 200 mils long of a typical thermistor material would have a resistance of about 5 to 7 million ohms at 25° C., a resistance much too high for most applications. Reducing the length and increasing the width of the thermistor film to 400 mils wide by 40 mils long to achieve the minimum resistance for a thermistor film of this type would lower the resistance to be in the order of 300,000 ohms at 25° C. As a result of the high resistivity of the thermistor material, printed thermistor films have heretofore had a resistance which is too high to be used for most applications. Printed thermistor films having a resistance in the order of 100 to 10,000 ohms at 25° C.

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have not been obtainable by the conventional resistor design described above.

It is an object of this invention to provide an improved thermistor assembly. It is still another object of this invention to provide a thermistor film assembly having a relatively low resistance. It is yet another object of this invention to provide a printed thermistor film assembly suitable for use in a printed circuit.

These and other objects are accomplished by a thermistor construction in which a thermistor film is sandwiched between two conductive films. This thermistor film assembly is supported on an insulative substrate. The thermistor film insulates the upper conductive film from the lower conductive film. The resistance of a given thermistor film assembly can be readily adjusted by changing the area of the upper conductive film. For example, increasing the area of the upper conductive film decreases the thermistor assembly resistance.

Other objects and advantages of this invention will be apparent from the following detailed description, reference being made to the accompanying drawings wherein the preferred embodiment of this invention is shown.

In the drawings:

FIGURE 1 is an elevational view partly in cross section of the thermistor assembly in accordance with this invention, and

FIGURE 2 is a cross sectional view of the thermistor assembly in FIGURE 1 taken along the lines 2—2.

Referring to FIGURES 1 and 2 of the drawings, thermistor assembly 10 is supported by the insulative substrate 12. The insulative substrate 12 is a thin layer or sheet of a ceramic or glass material having a thickness of about 25 to 40 mils thick. Commercially available fired alumina sheets are preferred although other insulative materials or ceramics may be employed.

The thermistor assembly 10 has a lower conductive film 14 which is printed on the substrate 12. The conductive film 14 has a portion thereof 16 which serves as a terminal and which is connected in an electrical circuit (not shown). The conductive film 14 may be palladium-silver, gold, gold-platinum or any other conductive film suitable for use in printed electrical circuitry. Conductive inks which are commercially available are well suited and preferred for preparing the conductive film 14. The thickness of the lower conductive film is about 0.4 to 1.2 mils with the preferred thickness being 0.7 mil.

Printed on top of the conductive film 14 is a thermistor film 18. The thermistor film is from 1 to about 10 mils thick with the preferred thickness being about 2 to 3 mils. Thicknesses less than 1 mil are subject to having pin holes therein which permit the transfer of current therethrough. Film thicknesses of 2 to 3 mils or more are preferred since the thickness is sufficient to be relatively free from pin holes. The thermistor film consists of 40 to 80 weight percent of a metal oxide and preferably a mixture of two or more oxides taken from the group consisting of copper oxide, manganese oxide, iron oxide, chromium oxide, cobalt oxide and nickel oxide and 20 to 60 weight percent of a low melting glass. A preferred thermistor film composition is a mixture containing 45 parts by weight manganese oxide, 55 parts cobalt oxide and 98 parts glass. Such a mixture has a resistivity in the range of 3×10^4 ohm-centimeters whereas cobalt oxide by itself has a resistivity of 10^7 ohm-centimeters and manganese oxide by itself has a resistivity of 4×10^8 ohm-centimeters. The particle size of the metal oxides should be less than 0.5 mil and preferably about .1 mil in size.

The presence of glass in the thermistor film is necessary in order to bond the thermistor material and to provide sufficient abrasion resistance so that the thermistor film can withstand the normal handling and the environ-

ments to which the film is exposed during manufacturing. Concentrations of glass below 20 weight percent do not provide sufficient bonding strength and abrasion resistance. Concentrations of glass above 60 weight percent are not satisfactory because the thermistor film becomes brittle and subject to crazing and/or cracking. The glass can be added as a powder or in the form of the commercially available glass paste which contains a carrier or solvent. The preferred particle size of the glass is less than 15 microns. The glass should have a coefficient of thermal expansion in the range of 6 to 9×10^{-6} per degree C. as well as a melting point between 450° and 800° C. Lead borosilicate glasses are preferred in the practice of this invention. A typical lead borosilicate glass useful in the practice of this invention contains 63 weight percent PbO , 25 weight percent B_2O_3 and 12 weight percent SiO_2 and has a melting point of 750° C. A commercially available lead borosilicate glass paste containing 75 weight percent solid material having a particle size of less than 15 microns and in which the glass melted between 500 and 550° C. worked satisfactorily.

Printed on top of the thermistor film 18 is the upper conductive film 20 which is sometimes referred to as the counter electrode. The upper conductive film 20 has a portion 22 thereof which serves as a terminal and which is connected in an electrical circuit (not shown). The conductive film 20 may be palladium-silver, gold, gold-platinum or any other conductive film suitable for use in printed electrical circuitry. Conductive inks which are commercially available are well suited and preferred for preparing the conductive film 20. The thickness of the upper conductive film is about 0.4 to 1.2 mils with the preferred thickness being about 0.7 mil. The upper conductive film 20 and the lower conductive film 14 are insulated from each other by the thermistor film 18.

The resistance of the thermistor assembly is determined by the resistivity of the thermistor composition, the thickness of the thermistor film which is the length of the current path, and by the cross sectional area of the upper conductive film as shown by the following formula:

$$\text{Resistance} = \frac{\text{Resistivity} \times \text{length of the current path}}{\text{Cross sectional area}}$$

The resistance of a thermistor assembly with a thermistor film of a certain composition having a given resistivity and a given film thickness, for example 3 mils, can be easily increased by decreasing the size of the upper conductive film and decreased by increasing the size of the upper conductive film. Although the most convenient way to change the resistance of the thermistor assembly is by increasing or decreasing the cross sectional area of the counter electrode or upper conductive film, the resistance of the thermistor assembly can also be changed by changing the thermistor composition so that the resistivity is different. The resultant resistance of the thermistor assembly can be made to be in the 100 to 10,000 ohm at 25° C. resistance range, a range which covers a substantial portion of most thermistor applications. The resistance of the thermistor assembly described in this invention is kept low by making the length of the current path, that is, the thermistor film thickness, small and by making the cross sectional area, that is the area of the upper conductive film or counter electrode, large.

The thermistor assembly of this invention is made by printing a conductive ink, for example palladium-silver, onto an alumina substrate so that the resultant film would be 0.5 to 0.7 mil thick. The conductive film is dried and then fired at a temperature of 760° C. In the manufacture of a hybrid integrated voltage regulator, for example, resistors are printed in series or parallel with the conductive lead 16 at this time and dried. A thermistor ink containing, for example, 20.6 weight percent cobalt oxide, 16.8 weight percent manganese oxide, 0.6 weight percent ethyl cellulose (binder), 11.9 weight percent diethylene glycol monobutylether (solvent and carrier) and 50 weight

percent glass paste containing 75 weight percent solids is printed onto the conductive film 14. The thermistor film is dried and a second layer of thermistor ink is printed on top of the first thermistor film and dried. The resultant thermistor film 18 has a combined thickness of about 2.4 mils. A conductive ink such as previously mentioned is then printed on top of the resultant thermistor film 18. The thermistor assembly is fired in an oven for a period of 40 to 50 minutes in which the temperature goes from room temperature to a peak temperature of about 760° C. where it is held for about 10 minutes and then back to room temperature. The resultant thermistor assembly has a resistance of from about 100 to 10,000 ohms or more at 25° C.

The present invention may be more fully understood in light of the following specific examples:

Example 1

A palladium-silver conductive ink was printed on an alumina substrate, dried and fired to form a conductive film 225 mils long by 225 mils wide by 0.7 mil thick. A thermistor ink composition containing 33 weight percent Co_3O_4 , 27 weight percent MnO_2 , 19 weight percent diethylene glycol monobutylether, 1 weight percent ethyl cellulose and 20 weight percent glass paste (75 weight percent solid) was printed on top of the lower conductive film and then dried. Another layer of the same thermistor ink was printed on top of the first thermistor film layer and dried. The resultant thermistor film had a thickness of 2.4 mils and was 240 mils long by 240 mils wide. The resistivity of this thermistor film material was defined as $RA=14$ ohm-in.² where R is the resistivity and A is the cross sectional area. The counter electrode or upper conductive film was formed on top of the thermistor film by printing with a palladium-silver conductive ink. The upper conductive film was 215 mils long by 215 mils wide by 0.7 mil thick. The thermistor assembly was placed in an oven and fired at a peak temperature of 760° C. for 10 minutes. The resistance of the thermistor assembly thus formed was 300 ohms at 25° C.

Example 2

A palladium-silver conductive film having a size of 125 mils long by 125 mils wide by 0.7 mil thick was formed as described in Example 1. A thermistor film was formed as described in Example 1 from a thermistor ink containing 23.7 weight percent Co_3O_4 , 12.9 weight percent MnO_2 , 12.8 weight percent diethylene glycol monobutylether, 0.6 weight percent ethyl cellulose and 50 weight percent glass paste (75% solid). The thermistor film was 140 mils wide by 140 mils long by 2.4 mils wide. The resistivity of this thermistor composition was defined as $RA=12.7$ ohm-in.². The upper conductive film was made from a palladium-silver ink and it had a size of 115 mils long by 115 mils wide by 0.7 mil thick. The thermistor assembly was fired as indicated in Example 1. The resistance of the thermistor assembly was 1,000 ohms at 25° C.

Example 3

A palladium-silver conductive film was printed having a size of 100 mils long by 100 mils wide by 0.7 mil thick. A thermistor film was printed from a thermistor ink containing 10.5 weight percent Co_3O_4 , 27.9 weight percent MnO_2 , 11.0 weight percent diethylene glycol monobutylether, 0.6 weight percent ethyl cellulose and 50 weight percent glass paste (75% solid). The thermistor film was 120 mils long by 120 mils wide by 2.4 mils thick. The resistivity of this thermistor composition was defined as $RA=350$ ohm-in.². The counter electrode was printed on top of the thermistor film with a palladium-silver ink and had a size of 85 mils long by 85 mils wide by 0.7 mil thick. The thermistor assembly was fired as indicated in Example 1. The resistance of the thermistor assembly was 50,000 ohms at 25° C.

As mentioned previously, this thermistor assembly is

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being used in a hybrid integrated voltage regulator. This assembly also has many applications in other printed electrical circuits since it provides a process which is compatible with the processing steps used in forming typical printed circuits. This thermistor assembly also provides a means of obtaining a low resistance thermistor assembly having a resistance in the range of 100 to 10,000 ohms or more at 25° C.

While the invention has been described in terms of specific examples, it is to be understood that the scope of the invention is not limited thereby except as defined in the following claims.

What is claimed is:

1. A thermistor assembly having a resistance between 100 and 100,000 ohms at 25° C. printed on an insulative substrate comprising a first conductive film printed on said substrate, said conductive film having a portion thereof adapted to be connected in an electric circuit,

a thermistor film consisting essentially of glass, cobalt oxide and manganese oxide printed on top of said first conductive film

and a second conductive film adapted to serve as a terminal printed on top of said thermistor film, said second conductive film being separated from first conductive film by said thermistor film, the area of said second conductive film being less than the area of said thermistor film, whereby said area of said second conductive film determines the resistance of said assembly to a substantial extent.

2. A thermistor assembly having a resistance between 100 and 100,000 ohms at 25° C., printed on an insulative substrate comprising a first conductive film printed on said substrate, said conductive film having a portion on

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one edge thereof adapted to be connected in an electric circuit,

a thermistor film one to ten mils in thickness consisting essentially by weight of 20% to 60% glass and 40% to 80% of manganese oxide and cobalt oxide printed on top of said first conductive film, said thermistor film having an end portion thereof overlapping another edge of said first conductive film and a second conductive film printed on top of said thermistor film, said second conductive film having a portion thereof extending over said thermistor film end portion onto said substrate to be connected in said electric circuit, said second conductive film being separated from said first conductive film by said thermistor film, the area of said second conductive film being less than the area of said thermistor film, wherein said area of said second conductive film determines the resistance of said assembly to a substantial extent.

References Cited

UNITED STATES PATENTS

3,408,311	10/1968	Short	338—22 X
2,966,646	12/1960	Baasch	338—22
3,015,633	1/1962	Humbert et al.	
3,219,480	11/1965	Girard	338—22 X

FOREIGN PATENTS

439,665	9/1948	Italy.
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