United States Patent

Brady et al.

[15] **3,688,238**

[45] **Aug. 29, 1972**

[54] **HERMETICALLY SEALED METAL-FILM RESISTOR**

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[73] Assignee: **Pyrofilm Corporation,** Whippany, N.J.

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[52] **U.S. Cl.** **338/237,** 174/50.61, 338/234, 338/268

[51] **Int. Cl.** **H01c 1/02**

[58] **Field of Search**.....338/237, 236, 234, 268, 271, 338/274, 277; 174/50.61, 525

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[57] **ABSTRACT**

A metal film resistor is disclosed as being encapsulated in a vitreous enclosure, e.g. a glass tube, the enclosure being hermetically sealed to conductive caps mounted on the resistor ends by the application of heat. The metal film of the resistance path of the resistor is protected from thermal damage during heat sealing by spacing the resistance path from the conductive caps and providing an electrical path therebetween in the form of an extended termination.

9 Claims, 6 Drawing Figures

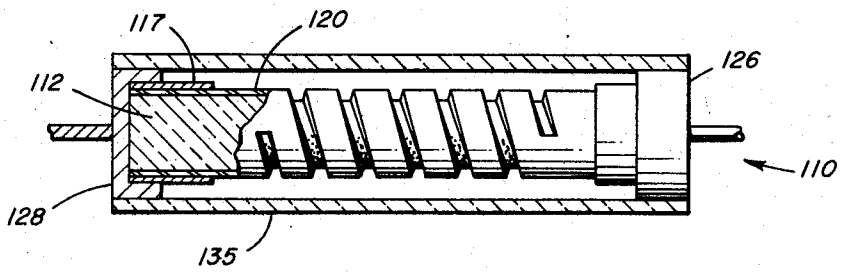


FIG. 1

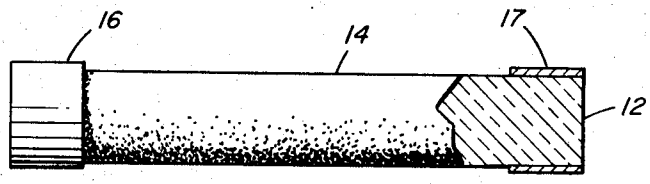


FIG. 2

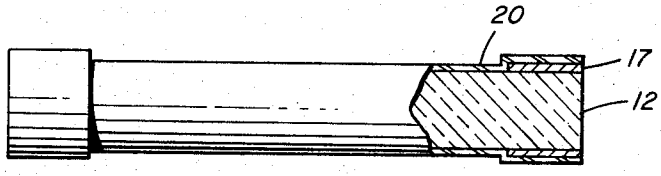
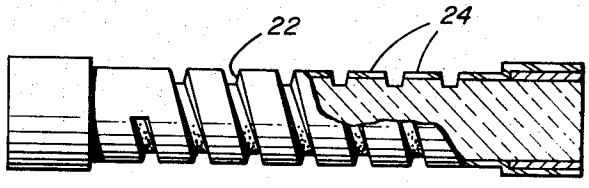


FIG. 3



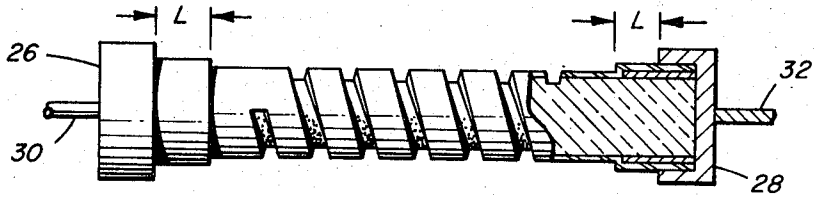


FIG. 4

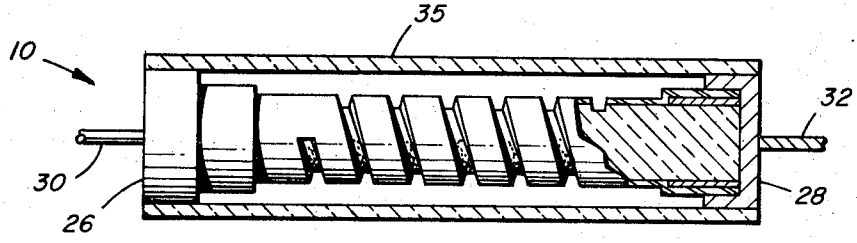


FIG. 5

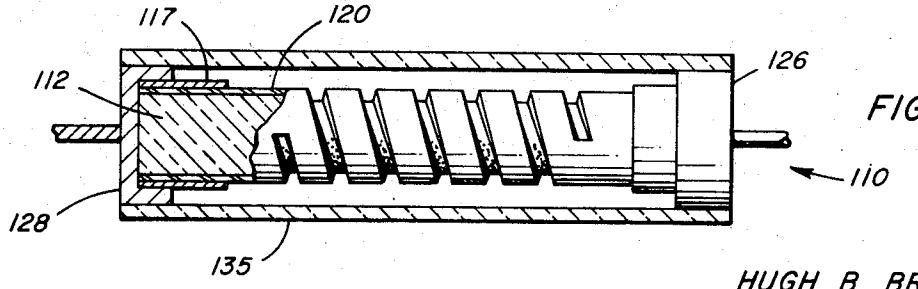


FIG. 6

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HERMETICALLY SEALED METAL-FILM RESISTOR

BACKGROUND OF THE INVENTION

This invention relates to the field of electrical resistors and in particular to electrical resistors having a film of metallic material for defining the resistance path.

Conventional metal film resistors comprise a film of suitable metallic material deposited on the exterior surfaces of a non-conductive base such as a porcelain-type ceramic cylinder. The ends of the resistor ordinarily are provided with conductive devices such as end caps which accommodate the attachment of leads for installing the resistor in a circuit to be served. The metal film of the resistance path if protected from oxidation and other deleterious effects by coating the resistor with an organic substance, e.g. a polymer coating, many types of which are generally known in the art.

Resistors which are encapsulated in organic materials are disadvantageous in many respects. Specifically, such resistors are limited to relatively low operating temperatures by the inability of the organic encapsulation to withstand temperatures in excess of 175° C. without degradation. Further, resistors which are encapsulated with organic materials have demonstrated a susceptability to changes in resistance characteristics after periods of storage, which changes ordinarily are the result of water vapor attack and reaction with environmental contaminants. The effects of water vapor attack and like occurrences of reaction are particularly serious in high value resistors which have an extremely thin film and which are provided with very closely spaced helical resistance paths.

The disadvantages of encapsulation with organic material are overcome by the use of vitreous material such as glass to encapsulate resistors. The use of such vitreous encapsulation is well known for non-metallic film resistors, see e.g. U.S. Pat. No. 2,930,018. However, non-metallic film resistors are more readily encapsulated in vitreous material than metal-film resistors because the temperatures required to effect a heat sealing of the glass on the resistor end caps do not cause damage to the non-metallic film. Metallic films, however, ordinarily have been damaged when subjected to the temperatures necessary for accomplishing heat sealing during vitreous encapsulation. The nature of the damage includes inter alia oxidation and crystallization of the metal film resulting in a reduction in or destruction of the operability of the resistor.

Attempts to avoid the thermally induced damage to the metal film of resistors while at the same time gaining the advantages of glass encapsulation have been made. One resistor constructed for this purpose comprises a metal film resistor element mounted within an encapsulation envelope including washers displaced from each end of the resistor element and a tubular glass element disposed concentrically of the resistor and sealed to the circumferential edges of the washers. Resistors constructed in this manner, although satisfactorily sealed, are disadvantageous because they effectively suspend the resistor element within the encapsulation envelope thus rendering it susceptible to vibration damage. Further, because of the line contact between the washers and the glass tube at the point of sealing, the resistors are expensive to manufacture and structurally fragile.

It is the principal object of the invention, therefore, to provide a metal film resistor which is encapsulated in a hermetically sealing vitreous material, e.g. glass, wherein the sealing material is secured directly to the resistor element.

SUMMARY OF THE INVENTION

The foregoing principal object and others not enumerated are accomplished by a hermetically sealed metal film resistor according to the invention, one embodiment of which may include a resistor element having a core, termination means and a layer of metal film disposed on said core, at least a portion of the metal film defining a resistor path, conductive means disposed on the core to define electrical input and output paths for the resistor, and a vitreous encapsulating means surrounding the resistor element and in sealing engagement with the conductive means.

BRIEF DESCRIPTION OF THE DRAWING

A more complete understanding of the invention may be had from the following detailed description, particularly when read in the light of the accompanying drawing wherein:

FIG. 1 is a plan view, partially in cross-section of a resistor core having terminations thereon:

FIG. 2 is a view similar to FIG. 1 and showing the addition of a metal film coating to the core and terminations;

FIG. 3 is a view similar to FIG. 2 and showing the addition of helical grooves to increase the length of the resistance path;

FIG. 4 is a view similar to FIG. 3 and showing the mounting of end cap conductive means on the ends of the core to define a resistor element;

FIG. 5 is a view similar to FIG. 4 and showing a vitreous encapsulation surrounding the resistor element and secured to the end caps; and

FIG. 6 is a view similar to FIG. 5 but of an alternative embodiment of metal film resistor according to the invention.

DETAILED DESCRIPTION

Considering the structure of a metal film resistor according to the invention, one embodiment of a completed resistor is shown in FIG. 5 and designated generally by the reference numeral 10. Various stages of the manufacture of resistor 10 are shown in FIGS. 1–4.

Referring therefore to FIG. 1, there is shown a resistor core 12 having a first end and a second end and a surface 14 for receiving thereon a coating of metal film. Core 12 may be one of many available non-conductive materials such as a porcelain type ceramic. However, selection of the material of the core must be coordinated with the selection of certain other materials of the resistor so as to match coefficients of thermal expansion as is discussed below in detail.

The first and second ends of core 12 are provided with first and second terminations 16 and 17, respectively. Each termination comprises a layer of material such as gold. The termination material e.g. gold, is deposited on the end portions of surface 14 by coating the ends with a gold resinate or other suitable material by known methods, and thereafter firing the coated core to decompose the resinate and leave the gold film.

With core **12** so terminated, it is then provided with a coating **20** of metal film by evaporation, sputtering or by any one of the other known metal filming processes. The entire core may be coated so as to cover terminations **16** and **17** as well as the exposed portion of surface **14**. It is only necessary, however, to cover the exposed portion of surface **14** and enough of terminations **16** and **17** to establish a good electrical contact therebetween. The metal film may be any of those known in the art, e.g. tantalum, and thick films of chromium silicon monoxide (cermets), the detailed description of the present invention, however, will be made with respect to a nickel chromium alloy being the metal film for coating **20**. After the metal film coating **20** has been deposited on the surface of core **12**, the coated core is heat treated to oxidize the metal film and stabilize its crystalline structure.

The surface of the coated core is then cut to form a helical groove **22** in the surface of the core so as to define a helical band **24** of metal film for increasing the effective length of the resistance path to provide a desired amount of circuit resistance. The forming of helical groove **22** may be accomplished by any of many known methods. It should be noted, however, that such grooves are not required, particularly for high frequency resistors, and their provision may be omitted without departing from the scope of the invention.

Either prior to or subsequent to the forming of helical groove **22**, a first end cap **26** is positioned over the first end of the coated core and a second end cap **28** is positioned over the second end of the coated core. Each end cap is manufactured of highly conductive material and dimensioned to frictionally engage and make good electrical contact with the metal film coating over first and second terminations **16** and **17** respectively. Lead in conductors **30** and **32** are secured to end caps **26** and **28**, respectively, so that each combination of cap and conductor defines a highly conductive path for the input and output of current to the resistor **10**. As is clearly shown in FIG. **4**, terminations **16** and **17** extend beyond end caps **26** and **28** respectively. Because the material of terminations **16** and **17** is highly conductive, the resistance path of resistor **10** is defined by that film of metal material disposed between terminations **16** and **17**. Further, it can be seen that terminations **16** and **17** extend beyond end caps **26** and **28** by a distance "L" so as to space the material of the resistance path from the end caps as is discussed below.

The capped structure shown in FIG. **4** defines a resistor element. This resistor element is positioned within a glass tube **35** so as to surround the resistor element including at least a portion of the peripheral surface of end caps **26** and **28**. With the resistor element positioned within glass tube **35**, heat is applied to the ends of the tube to cause shrinkage of the glass against the end caps and the establishment of a hermetic seal therebetween to finally form resistor **10**. If desired, a coating of paint or other suitable material may be applied, but such a coating is not necessary to the invention and may be provided without departing from the scope thereof.

As noted above, the terminations **16** and **17** extend longitudinally beyond end caps **26** and **28** by a distance "L" so as to separate the resistance path of resistor **10** from end caps **26** and **28**. This arrangement is particularly unique when compared with known resistor structures and is provided for the purpose of isolating the metal film of the resistance path of the resistor from the heat experienced in the vicinity of end caps **26** and **28** during heat sealing of glass tube **35** thereto. More specifically, with respect to most known metal film resistors, the heat required to accomplish a heat seal between glass tube **35** and end caps **26** and **28** is in the range of 1,500° C. applied to the glass for one minute and is such as to cause damage to the metal film of the resistance path by oxidation and crystallization of the film material. Thus, unless the sealing heat is abated in some manner, the process of sealing a metal film resistor destroys the resistance material. The present invention accomplishes the heat abatement by extending terminations **16** and **17** beyond conductive caps **26** and **28** to separate the material of the resistance path from the immediate area of the heat sealing process. In this manner, the resistor materials including the cap, core and terminations act as a heat sink to lessen progressively the temperature experienced on the surface of the resistor element at points displaced from the cap. The amount of required separation, i.e. the dimension "L," is a function inter alia of the metal film material, the temperature and duration requirement for heat sealing, and the heat absorbing characteristics of the resistor element. Thus, the dimension "L" should be determined for any particular resistor and such a determination is well within the skill of those in this art.

Considering an example of a resistor structured in accordance with the invention, it has been found that permanent damage to nickel-chromium alloy metal film occurs when the film is subjected to temperature in excess of 510°–525° C. Thus, for a resistor utilizing such a film, the dimension "L" must be sufficiently large to allow a heat dissipation between the end caps and material of the resistance path to reduce the temperature at the surface of the core from that experienced at the end caps to below 500° C. A resistor having a core of 0.157 inch diameter ALSIMAG 531 as manufactured by American Lava Corp.; KOVAR end caps which extend 0.074 inches over the terminations, the material for which is available from the Westinghouse Corporation; terminations of gold which extend 0.141 inches beyond the end of the end cap; and a glass tube encapsulation has been manufactured without the occurrence of thermal damage to a metal film material comprising substantially an 80 percent nickel- 20 percent chromium alloy.

It should be noted at this stage that materials for resistors encapsulated in vitreous material should be selected carefully to provide matching coefficients of thermal expansion. This requirement which is discussed in detail in the above noted U.S. Pat. No. 2,930,018, provides that the resistor core, conductive end caps and vitreous encapsulation material have substantially the same coefficients of thermal expansion so that resistor damage will not occur during operation. In this regard, the above noted example of a resistor having an ALSIMAG 531 core, KOVAR end caps and glass encapsulation possesses the required matching coefficients of thermal expansion.

In view of the foregoing, it can be seen that metal film resistors can be provided with glass encapsulation which is secured directly to the resistor element. Such a construction enables the utilization of the advantages

of glass sealing with the elimination of the previously experienced fragility and difficulty of manufacture.

An alternative embodiment of resistor according to the invention is shown in FIG. **6** and designated generally by the reference numeral **110**. Resistor **110** includes a core **112**, a coating **120** of metal film, terminations **117** and **116** (not shown), end caps **126** and **128** and a glass encapsulation tube **135**. The only difference between the resistor embodiment of FIG. **5** and that of FIG. **6** is the relative positioning of the coating of metal film and the terminations. More specifically, in the resistor **10**, terminations **16** and **17** are disposed under the coating of metal film whereas in the resistor **110**, the terminations **116** and **117** are disposed over the coating of metal film.

Resistors according to the present invention, therefore, have vitreous encapsulation structure sealed directly to the resistor element thereby providing a stronger, less expensive and more stable product.

It is considered to be manifest that many modifications and variations to the present invention can be accomplished without departing from the spirit and scope thereof.

What is claimed is:

1. A hermetically sealed metal film resistor comprising:

a resistor element including a core, termination means and a layer of metal film disposed on said core, at least a portion of said metal film defining a resistance path;

conductive means disposed on said core, said conductive means defining electrical input and output paths for said resistor; and

vitreous encapsulating means surrounding said resistor element and in sealing engagement with said conductive means, said vitreous encapsulating means being directly secured to said conductive means by heat sealing and said metal film of said resistance path being separated longitudinally from said conductive means by at least a portion of said termination means.

2. A resistor according to claim **1** wherein said portion of said termination means separates said metal film of said resistance path from said conductive means by an amount sufficient to preclude thermal damage to said metal film of said resistance path during heat sealing of said vitreous encapsulating means to said conductive means.

3. A resistor according to claim **1** wherein said metal film is a nickel chromium alloy and said portion of said termination means separates said metal film of said resistance path form said conductive means by an amount sufficient to maintain the temperature of said metal film of said resistance path below 500° C. during heat sealing of said vitreous encapsulating means to said conductive means.

4. A hermetically sealed metal film resistor comprising:

a base having a first end and a second end,

a first termination extending longitudinally on said base from said first end;

a second termination extending longitudinally on said base from said second end;

a film of metallic material disposed on said base and extending at least between said terminations to define a resistance path;

a first conductive means disposed on said first termination;

a second conductive means disposed on said second termination;

a vitreous encapsulating means surrounding said film of metallic material, said vitreous encapsulating means being directly heat sealed to said first and second conductive means, respectively; and wherein

said metallic film of said resistance path is separated longitudinally from said first and second conductive means by said first and second terminations, respectively.

5. A resistor according to claim **4** wherein said separation of said metallic film of said resistance path from said conductive means is of sufficient length to preclude thermal damage to said metal film of said resistance path during heat sealing of said vitreous encapsulated means to said first and second conductive means.

6. A resistor according to claim **4** wherein said metallic film comprises a nickel chromium alloy and said separation of said metallic film of said resistance path from said conductive means is sufficient to maintain the temperature of said metal film of said resistance path below 500° C during heat sealing of said vitreous encapsulating means to said conductive means.

7. A hermetically sealed metal film resistor comprising:

a base having a surface, said surface having a first end and a second end;

a first termination on said surface adjacent said first end, said first termination comprising a layer of conductive material disposed on said first surface from said first end and over a portion of the length of said base;

a second termination on said surface adjacent said second end, said second termination comprising a layer of conductive material disposed on said surface from said second end over a portion of the length of said base;

a film of metallic conductive material disposed on said surface and on at least a portion of each of said first and second terminations, said film of metallic conductive material on said surface between said first and second terminations defining a resistance path;

a first conductive cap on said first end of said base, said first conductive cap being in electrically conductive engagement with said film of metallic conductive material;

a second conductive cap on said second end of said base, said second conductive cap being in electrically conductive engagement with said film of metallic conductive material;

and

vitreous encapsulating means surrounding said surface, said encapsulating means being directly heat sealed to said first and second conductive caps to define a hermetic seal therewith;

said metallic film of said resistance path being separated longitudinally from said first and second conductive caps by said first and second termination means, respectively.

8. A resistor according to claim **7** wherein said separation between said first and second conductive

caps and said film of metallic conductive material of said resistance path is of sufficient length to preclude thermal damage to said film of metallic conductive material of said resistance path during heat sealing of said vitreous encapsulating means to said first and second conductive caps.

9. A resistor according to claim 7 wherein said separation between said first and second conductive caps and said film of metallic conductive material of said resistance path is of sufficient length to maintain the temperature of said metallic conductive material of said resistance path below 500° C. during heat sealing of said vitreous encapsulating means to said first and second conductive caps.

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